OPERATING AND SERVICE MANUAL

PRELIMINARY

DC POWER SUPPLY

DPB SERIES

MODEL 6228B

HEWLETT hp PACKARD

HEWLETT hp PACKARD

CERTIFICATION

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from date of delivery, or in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard. No other warranty is expressed or implied. We are not liable for consequential damages.

For any assistance contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

PRELIMINARY

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OPERATING AND SERVICE MANUAL

FOR SERIALS 0E0101 AND ABOVE*

*For Serials Above 0E0101
A change page may be included.

100 Locust Avenue, Berkeley Heights, New Jersey 07922

HP Part No. 06228-90001

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SECTION I
GENERAL INFORMATION

1-1 DESCRIPTION

1-2 This instrument is designed to be used in applications such as powering operational amplifiers, push-pull stages, and deflection systems where plus and minus voltages are required to track with an insignificant error, and in any application where two independent power supplies housed in a single package represent an operating convenience.

1-3 The instruments consists of two identical, independently adjustable dc power supplies in a half-rack case. A front panel switch selects one of two modes of operation: independent or tracking. In the independent mode, the output voltage and current of each supply are controlled separately, and each supply is isolated up to 300V from output to chassis or output to output. In the tracking mode, both outputs are automatically connected in series, and the controls of the left supply adjust the magnitudes of both the positive and negative output voltages. Because the outputs are connected in a tracking configuration, any internal disturbance (such as drift or ripple) will cause an equal percentage change in the outputs of both the supplies.

1-4 Each power supply is a completely transistorized, well-regulated, constant voltage/constant current supply that will furnish full rated output voltage at the maximum output current or can be continuously adjusted throughout the output range. The front panel CURRENT controls can be used to establish the output current limit (overload or short circuit) when the supply is used as a constant voltage source (independent or tracking modes), and the VOLTAGE controls can be used to establish the voltage limit (ceiling) when the supply is used as a constant current source (independent mode only). The supply will automatically cross over from constant voltage to constant current operation (current limited operation in the tracking mode) and vice versa if the output current or voltage exceeds these preset limits.

1-5 Each supply has its own front panel meter that can measure output voltage or current. The front panel METER switch on each supply selects either of the two functions.

1-6 Each supply has a built in overvoltage protection crowbar for the protection of delicate loads. The crowbar sets a limit (adjustable from the front panel) on the output voltage. If this limit is exceeded, a short circuit is applied across the output of the supply.

1-7 Both front and rear output terminals are provided on each supply. Either set of terminals can be used in the independent mode; only the front terminals can be used when the instrument is operated in the tracking mode. Either the positive or negative output terminals can be connected to the chassis through a separate ground terminal located adjacent to the output terminals, or the supply can be operated floating at up to a maximum of 300 volts above ground.

1-8 Terminals located at the rear of each power supply allow access to various control points within the supply to expand the operating capabilities of the power supply. A brief description of these capabilities is given below:

a. Remote Programming. In the independent mode, the output voltage or current of each supply may be programmed (controlled) from a remote location by means of an external voltage source or resistance connected to each supply. In the tracking mode, the output voltage of both supplies may be programmed from a remote location by means of an external voltage source or resistance connected to the left supply.

b. Remote Sensing. The degradation in regulation which occurs at the load due to voltage drop in the load leads can be reduced by employing remote sensing. This is possible with the instrument in the independent mode of operation only.

c. Auto-Series Operation. Two or more power supplies may be used in series when a higher output voltage is required in the constant voltage mode of operation or when greater voltage compliance is required in the constant current mode of operation. Auto-Series operation permits one-knob control of the total output voltage from a "master" supply.

d. Auto-Parallel Operation. Each individual power supply may be operated in parallel with one or more similar units when greater output current capability is required. Auto-Parallel operation permits one-knob control of the total output current from a "master" supply.

e. Auto-Tracking Operation. One power supply may be used as a "master" supply controlling one or more "slave" supplies furnishing various voltages for a system. When operated with the

front panel mode switch in the tracking position, the instrument is automatically internally connected in an Auto-Tracking configuration.

1-9 SPECIFICATIONS

1-10 Detailed specifications for the instrument are given in Table 1-1. Unless otherwise noted, the specifications apply equally to both of the independent supplies housed in the instrument.

1-11 OPTIONS

1-12 Options are customer-requested factory modifications of a standard instrument. The following options are available for the instrument covered by this manual. Where necessary, detailed coverage of the options are included throughout the manual.

Option No.	Description
007	Ten-Turn Output Voltage Controls: Two single ten-turn controls that replace both sets of concentric coarse and fine voltage controls. The controls allow greater resolution in setting the output voltage of each supply.
008	Ten-Turn Output Current Controls: Two single ten-turn controls that replace both sets of concentric coarse and fine current controls. The controls allow greater resolution in setting the output current of each supply.
009	Ten-Turn Output Voltage and Current Controls: Options 007 and 008 on the same instrument.
013	Three Digit Ten-Turn Graduated Decadial Current Controls: Two single ten-turn controls with Decadials that replace both sets of concentric coarse and fine voltage controls. The controls allow accurate resetting of the output voltage of each supply.
014	Three Digit Ten-Turn Graduated Decadial Current Controls: Two single ten-turn controls with Decadials that replace both sets of concentric coarse and fine current controls. The controls allow accurate resetting of the output current of each supply.
015	Three Digit Ten-Turn Graduated Decadial Voltage and Current Controls. Options 013 and 014 on the same instrument.

1-13 ACCESSORIES

1-14 The accessories listed in the following chart may be ordered with the instrument or separately from your local Hewlett-Packard sales office (refer to list at rear of manual for addresses).

HP Part or Model No.	Description
1052A	Combining Case for mounting one or two units in standard 19" rack (refer to Section II for details).
5060-0789	Cooling kit for above combining case, 115Vac, 50-60Hz.
5060-0796	Cooling kit for above combining case, 230Vac, 50-60Hz.
5060-0794	Filler panel to block unused half of above combining case when mounting only one unit.

1-15 INSTRUMENT IDENTIFICATION

1-16 Hewlett-Packard power supplies are identified by a three-part serial number. The first part is the power supply model number. The second part is the serial number prefix, consisting of a number-letter combination denoting the date of a significant design change and the country of manufacture. The first two digits indicate the year (10 = 1970, 11 = 1971, 20 = 1980, etc); the second two digits indicate the week (01 through 52); and the letter "A", "G", "J", or "U" designates the U.S.A., West Germany, Japan, or the United Kingdom, respectively, as the country of manufacture. The third part is the power supply serial number; a different 5-digit sequential number is assigned to each power supply, starting with 00101.

1-17 If the serial number prefix on your unit does not agree with the prefix on the title page of this manual, change sheets supplied with the manual or manual backdating changes in Appendix A define the differences between your instrument and the instrument described by this manual.

1-18 ORDERING ADDITIONAL MANUALS

1-19 One manual is shipped with each instrument. Additional manuals may be purchased from your local Hewlett-Packard field office (see list at rear of this manual for addresses). Specify the model number, serial number prefix, and HP part number shown on the title page.

Table 1-1. Specifications

INPUT:
115/230Vac ±10%, single phase, 48-66Hz, 2.7A, 260W @ 115V.

OUTPUT:
Independent Mode - Two independent outputs, each of which can be set from 0-50 volts at 0-1 ampere.
Tracking Mode - Tracking outputs of 0 to ±50 volts at 1 ampere each.

LOAD REGULATION:
Constant Voltage - Less than 0.01% plus 1mV for a load current change equal to the current rating of the supply.
Constant Current - Less than 0.01% plus 250µA for a load voltage change equal to the voltage rating of the supply.

LINE REGULATION:
Constant Voltage - Less than 1mV for a change in line voltage from 103.5 to 126.5V at any output voltage and current within rating.
Constant Current - Less than 100µA for a line voltage change from 103.5 to 126.5V at any output voltage and current within rating.

RIPPLE AND NOISE:
Constant Voltage - Less than 250µVrms, 4mV p-p (dc to 20MHz).
Constant Current - Less than 250µArms, 2mA p-p (dc to 20MHz).

TEMPERATURE RATINGS:
Operating: 0 to 55°C. Storage: -40 to +75°C.

TEMPERATURE COEFFICIENT:
Constant Voltage - Less than 0.02% plus 200µV change per degree Centigrade change in ambient following 30 minutes warm-up.
Constant Current - Less than 0.02% plus 150µA change per degree Centigrade change in ambient following 30 minutes warm-up.

STABILITY:
Constant Voltage - Less than 0.2% plus 2mV total drift for 8 hours following 30 minutes warm-up under constant ambient conditions.
Constant Current - Less than 0.2% plus 1.5mA total drift for 8 hours following 30 minutes warm-up under constant ambient conditions.

OUTPUT IMPEDANCE:
A 6mΩ resistor in series with a 6µH inductor.

WEIGHT:
24 lbs. (11 Kg) net. 28 lbs. (12,9 Kg) shipping.

TRANSIENT RECOVERY TIME:
Less than 50µsec is required for output voltage recovery (in constant voltage operation) to within 10mV of the nominal output voltage following a 1 ampere change in output current.

METERS:
Each front panel meter can be used as either a 0-60V voltmeter or a 0-1.2A ammeter. Meters are accurate within 2% of full scale; meter switch selects voltage or current readings.

OUTPUT CONTROLS:
Single-turn concentric coarse and fine voltage and current controls are included on the front panel. Mode switch selects one of two modes of operation: either two independent, isolated outputs; or the two outputs connected in series and referred to a common bus for tracking.

SLAVE TRACKING ERROR:
During tracking operation, the slave supply is matched to within 0.2% ±2mV of the master supply.

REMOTE VOLTAGE PROGRAMMING:
All programming terminals on rear barrier strips.
Constant Voltage - 1V/volt.
Constant Current - 1V/ampere.

REMOTE RESISTANCE PROGRAMMING:
All programming terminals on rear barrier strips.
Constant Voltage - 200 ohms/volt.
Constant Current - 1000 ohms/ampere.

OVERVOLTAGE PROTECTION CROWBAR:
During independent operation, each supply is protected by its own crowbar. In the tracking mode, an overvoltage in either supply results in firing both crowbars. The minimum crowbar trip setting above the desired operating output voltage to prevent false crowbar tripping is 7% of output voltage setting plus 1.5 volt. Trip voltage range is 5 to 55Vdc.

COOLING:
Convection cooling is employed. The supply has no moving parts.

SIZE:
6-17/32" (16,59cm) H x 12-3/8" (31,43cm) D x 7-3/4" (19,69cm) W.

FINISH:
Light gray panel with dark gray case.

2-1 INITIAL INSPECTION

2-2 Before shipment, this instrument was inspected and found to be free of mechanical and electrical defects. As soon as the instrument is received, proceed as instructed in the following paragraphs.

2-3 MECHANICAL CHECK

2-4 If external damage to the shipping carton is evident, ask the carrier's agent to be present when the instrument is unpacked. Check the instrument for external damage such as broken controls or connectors, and dents or scratches on the panel surfaces. If the instrument is damaged, file a claim with the carrier's agent and notify your local Hewlett-Packard Sales and Service Office as soon as possible (see list at rear of this manual for addresses).

2-5 ELECTRICAL CHECK

2-6 Check the electrical performance of the instrument as soon as possible after receipt. Section V of this manual contains performance check procedures which will verify instrument operation within the specifications as stated in Table 1-1. This check is also suitable for incoming quality control inspection. Refer to the inside front cover of the manual for the Certification and Warranty statements.

2-7 REPACKAGING FOR SHIPMENT

2-8 To insure safe shipment of the instrument, it is recommended that the package designed for the instrument be used. The original packaging material is reusable. If it is not available, contact your local Hewlett-Packard field office to obtain the materials. This office will also furnish the address of the nearest service office to which the instrument can be shipped. Be sure to attach a tag to the instrument specifying the owner, model number, full serial number, and service required, or a brief description of the trouble.

2-9 INSTALLATION DATA

2-10 The instrument is shipped ready for bench operation. It is necessary only to connect the instrument to a source of power and it is ready for operation.

2-11 LOCATION

2-12 This instrument is convection cooled. Sufficient space should be allotted so that a free flow of cooling air can reach the top and rear of the instrument when it is in operation. It should be used in an area where the ambient temperature remains between 0°C and +55°C.

2-13 OUTLINE DIAGRAM

2-14 Figure 2-1 illustrates the outline shape and dimensions of the Model 6227B and 6228B supplies.

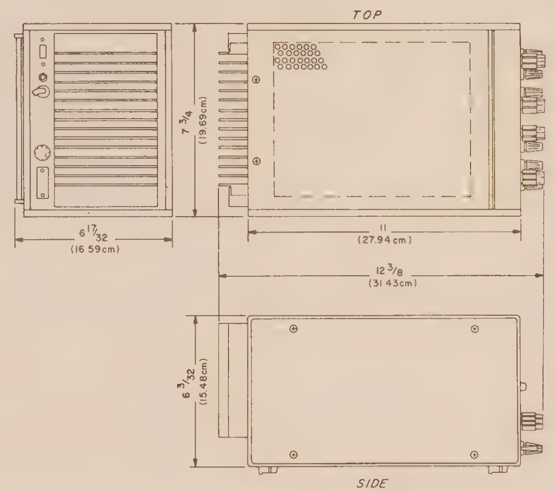


Figure 2-1. Outline Diagram

2-15 RACK MOUNTING

2-16 The Model 6227B and 6228B power supplies are submodular units, which, when used alone, can be bench mounted only. However, when used in combination with other submodular units, they can be bench and/or rack mounted in the HP combining case which is specifically designed for this purpose. The HP "Rack Adapter Frame" cannot be used due to the weight of the instruments.

2-17 The combining case is a full-module unit which accepts varying combinations of submodular units. Since it is a full-module unit, it can be bench or rack mounted analogous to any full-module HP instrument. A cooling kit (see

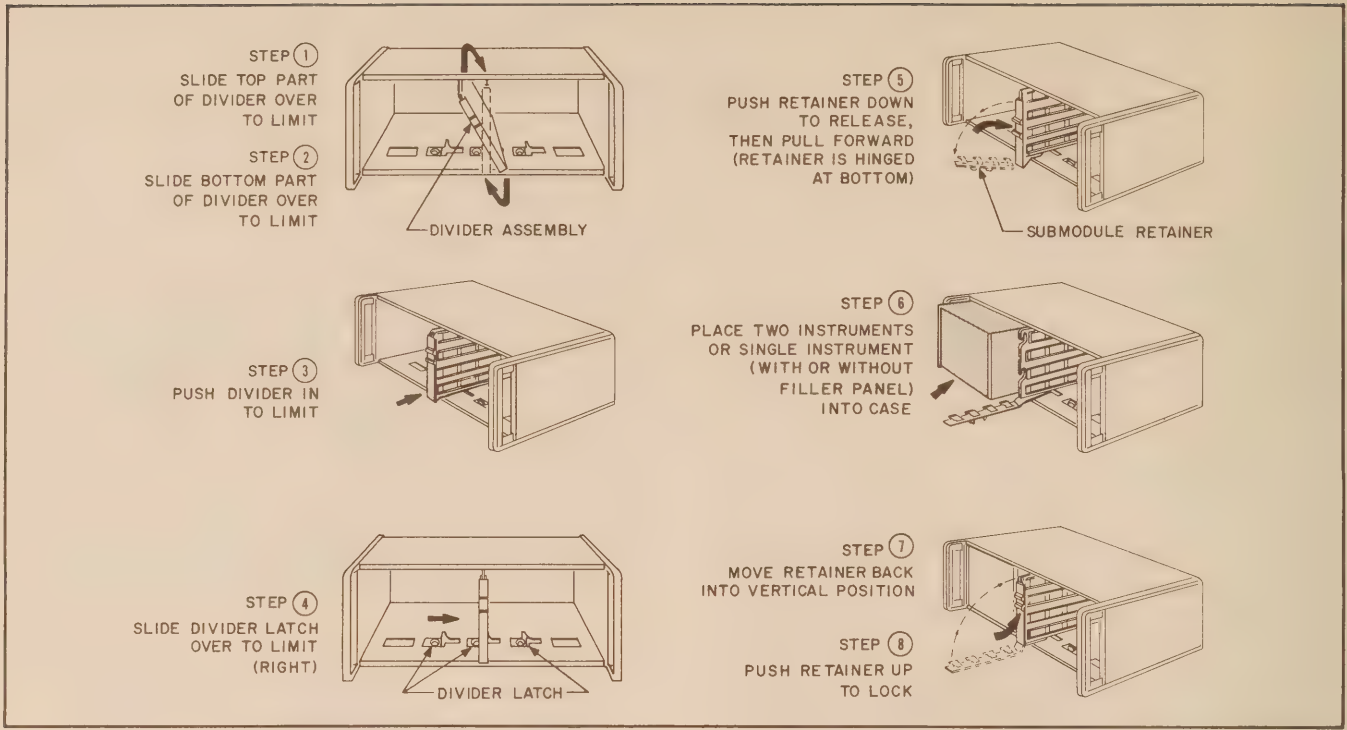


Figure 2-2. Procedure for Installing Instrument(s) in HP Combining Case

Paragraph 1-14 for HP Part No.) must be installed at the rear of the combining case when operating either one or two Model 6227B or 6228B power supplies in the case. Instructions for installing the Model 6227B or 6228B power supplies in the combining case are given in Figure 2-2.

2-18 To rack mount the combining case in a standard rack, proceed as follows:

a. Remove gray plastic trip strips (glued on) at each side of case by inserting thin screwdriver at edge or top of strip and prying gently away from case.

b. Attach rack ears (furnished with each combining case) to side of case using screws supplied with ears.

c. Mount unit in rack, using standard mounting screws.

2-19 INPUT POWER REQUIREMENTS

2-20 This power supply may be operated continuously from either a nominal 115 volt or 230 volt, 48-66Hz power source. The input power required when operating from a 115 volt, 60Hz power source at full load is 260 watts, 2.7 amperes.

2-21 115/230 VOLT OPERATION

2-22 A recessed, two-position slide switch located on the lower rear panel permits operation from either a 115 or 230 volt power source. Before connecting the instrument to the power source, check that the white number visible on the switch slide matches the nominal line voltage of the source. If required, slide the switch to the other position using a thin-bladed screwdriver.

2-23 When the instrument leaves the factory, the proper fuse is installed for 115 volt operation. An envelope containing a fuse for 230 volt operation is attached to the instrument. Markings on the lower rear panel adjacent to the fuse holder indicate the correct fuse rating for operation from either a 115 volt or a 230 volt power source. Make sure that the correct fuse is installed if the position of the slide switch is changed.

2-24 POWER CABLE

2-25 To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a three conductor power cable. The third conductor is the ground conductor and when the cable is plugged into an appropriate receptacle, the instrument is grounded. The offset pin on the power cable's three-prong connector is the ground connection.

2-26 To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green lead on the adapter to ground.

SECTION III
OPERATING INSTRUCTIONS

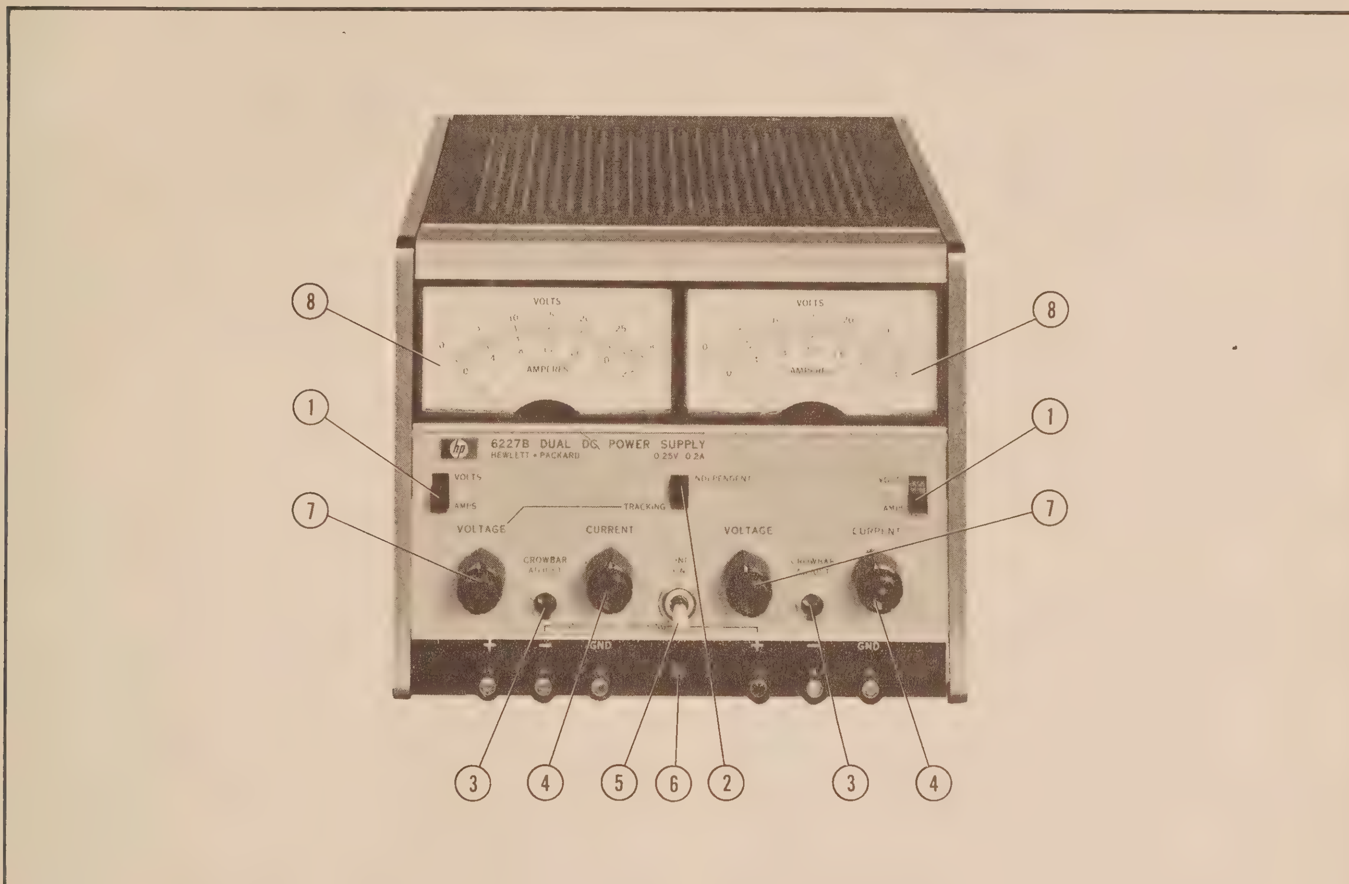


Figure 3-1. Operating Controls and Indicators

3-1 TURN-ON CHECKOUT PROCEDURE

3-2 The following checkout procedure describes the use of the front panel controls and indicators (Figure 3-1) and ensures that the supply is operational. This procedure should be performed with no load connected to the supply.

a. Set both meter switches (1) to VOLTS, set mode switch (2) to INDEPENDENT, rotate both CROWBAR ADJUST controls (3) (screwdriver adjust) fully clockwise, and rotate both sets of CURRENT controls (4) to middle of range (black knobs are coarse controls, red knobs are fine controls).

b. Set LINE switch (5) to ON, and observe that pilot lamp (6) lights.

c. Adjust both sets of VOLTAGE controls (7) (black knobs are coarse controls, red knobs are fine controls) until desired output voltages are indicated on meters (8) .

d. To ensure that overvoltage crowbar circuit is operational, rotate each OVERVOLTAGE ADJUST control counterclockwise until associated supply crowbars. Output voltage of each supply will fall to approximately one volt.

e. To deactivate each crowbar, return its OVERVOLTAGE ADJUST control to maximum clockwise position and turn off supply. Turn supply back on and output voltages should again be value obtained in Step (c).

f. To check out constant current circuit, turn off supply. Short circuit both sets of front panel output terminals (plus to minus), rotate both sets of VOLTAGE controls to middle of range, set both meter switches to AMPS, and turn on supply.

g. Adjust both sets of CURRENT controls until desired output currents are indicated on meters.

h. To check out tracking mode of operation,

turn off supply, remove short circuits across output terminals, rotate both sets of CURRENT controls to middle of range, rotate both sets of VOLTAGE controls fully counterclockwise, set both meter switches to VOLTS, connect jumper between minus output terminal of left supply and plus output terminal of right supply as shown on front panel, and set mode switch to TRACKING.

i. Turn on supply and adjust left (master) set of VOLTAGE controls until desired output voltage is indicated on both meters.

j. To check out operation of overvoltage crowbar in tracking mode, rotate either OVERVOLTAGE ADJUST control until both supplies crowbar. Output voltage of both supplies will fall to approximately one volt.

k. To deactivate both crowbars, return OVERVOLTAGE ADJUST control to maximum clockwise position and turn off supply. Turn supply back on and both output voltages should again be value obtained in Step (i).

l. Turn off supply and read following paragraphs before connecting acutal load to supply.

3-3 BASIC OPERATING MODES

3-4 The instrument has two basic modes of operation: INDEPENDENT, in which the instrument functions as two completely separate power supplies, and TRACKING, in which the instrument functions as a single power supply having two opposite polarity, tracking outputs. Either of these two modes can be selected by simply changing the position of the front panel mode switch. Additional operating modes such as remote programming in the TRACKING mode and series-parallel connections in the INDEPENDENT mode can be selected by making strapping connections between particular terminals on the terminal strips at the rear of the instrument (refer to Paragraphs 3-39 and 3-50). The following paragrpahs describe the procedures for utilizing these various operational capabilities of the instrument. A more theoretical description of the operational features of the two power supplies is contained in Application Note 90, Power Supply Handbook (available at no charge from your local Hewlett-Packard sales office). Sales office addresses appear at the rear of the manual.

3-5 INDEPENDENT OPERATION

3-6 The instrument functions as two completely independent power supplies when the front-panel mode switch is in the INDEPENDENT position. In this mode the operating procedures for each supply are identical, and thus the following paragraphs describe procedures for one supply only.

3-7 The instrument is normally shipped with each supply's rear terminal strapping connections arranged for constant voltage/constant current, local sensing, local programming, single unit mode of operation. This strapping pattern is illustrated in Figure 3-2. The operator selects either a constant voltage or a constant current output using the front panel controls (local programming; no strapping changes are necessary).

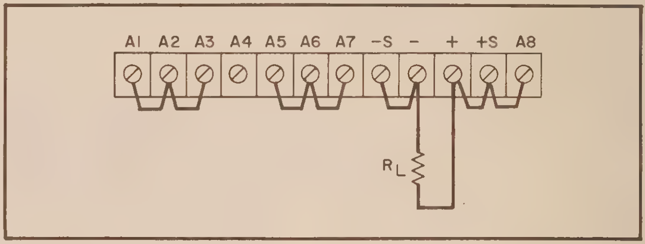


Figure 3-2. Normal Strapping Pattern

3-8 CONSTANT VOLTAGE

3-9 To select a constant voltage output, proceed as follows:

a. Turn on power supply and adjust VOLTAGE controls (with meter switch in VOLTS position) for desired output voltage with output terminals open.

b. Short circuit output terminals and adjust CURRENT controls (with meter switch in AMPS position) for maximum output current allowable (current limit), as determined by load conditions. If a load change causes the current limit to be exceeded, the power supply will automatically cross over to constant current output at the preset current limit and the output voltage will drop proportionately. In setting the current limit, allowance must be made for high peak currents which can cause unwanted crossover. (Refer to Paragraph 3-79.)

3-10 CONSTANT CURRENT

3-11 To select a constant current output, proceed as follows:

a. Short circuit output terminals and adjust CURRENT controls (with meter switch in AMPS position) for desired output current.

b. Open circuit output terminals and adjust VOLTAGE controls (with meter switch in VOLTS position) for maximum output voltage allowable (voltage limit), as determined by load conditions. If a load change causes the voltage limit to be exceeded, the power supply will automatically crossover to constant voltage output at the preset voltage limit and the output current will drop proportionately. In setting the voltage limit, allowance must be made for high peak voltages which can cause unwanted crossover. (Refer to Paragraph 3-79.)

3-12 OVERVOLTAGE CROWBAR OPERATION

3-13 Trip Point Adjustment. The crowbar trip voltage can be adjusted by using the screwdriver control (CROWBAR ADJUST) on the front panel. The trip voltage range is as follows (clockwise rotation of the control produces higher trip voltages):

6227B 5 to 28Vdc
6228B 5 to 55Vdc

To adjust the trip point, proceed as follows:

a. Turn CROWBAR ADJUST control fully clockwise and turn on supply.

b. Set output voltage to desired trip voltage.

c. Turn CROWBAR ADJUST control slowly counterclockwise until crowbar is tripped (voltmeter falls to one volt or less).

d. Turn off supply and turn down output voltage.

e. Turn on supply and set desired operating output voltage.

3-14 False crowbar tripping must be considered when adjusting the trip point. If the trip voltage is set too close to the operating output voltage of the supply, a transient in the output or load will falsely trip the crowbar. It is recommended that the crowbar trip voltage be set higher than the operating output voltage by 7% plus 1.5 volts.

3-15 Operating Characteristics. When the crowbar trips, the supply output is shorted by an SCR. The output voltage then falls to one volt or less (the forward voltage drop of the SCR), and the current supplied to the load falls to essentially zero. Note that once the crowbar is tripped, the ammeter indicates the current flowing through the SCR. This current is determined by the setting of the CURRENT controls, just as it would be if an external short were connected across the output terminals. If the CURRENT controls are set to a very low level (less than 0.05 ampere), the current supplied to the SCR when the crowbar trips may not be enough to keep the SCR conducting. In this case, the crowbar will oscillate, and the output voltage will cycle between zero and the crowbar trip level. This condition can be prevented by setting the CURRENT controls at a slightly higher level.

3-16 Crowbar Reset. The crowbar may be reset by either of two methods. If the crowbar tripped due to a transient in the output or load, it can be reset by simply turning the power switch off and then on again. The crowbar can also be reset in this manner if it tripped due to the application of an external voltage higher than the output voltage across the output terminals. If the crowbar tripped due to accidentally setting the output voltage higher than intended, it can be reset by turning the VOLTAGE controls down to zero and then back up to the normal operating voltage.

3-17 CONNECTING LOAD

3-18 Each load should be connected to the power supply output terminals (front or rear) using separate pairs of connecting wires. This will minimize mutual coupling effects between loads and will retain full advantage of the low output impedance of the power supply. Each pair of connecting wires should be as short as possible and twisted or shielded to reduce noise pickup. (If a shielded pair is used, connect the shield to ground at the power supply and leave the other end unconnected.)

3-19 If load considerations require that the output power distribution terminals be remotely located from the power supply, then the power supply output terminals should be connected to the remote distribution terminals via a pair of twisted or shielded wires and each load should be separately connected to the remote distribution terminals. For this case, remote sensing should be used. (Refer to Paragraph 3-61.)

3-20 Positive or negative voltages can be obtained from the supply by grounding either one of the output terminals or one end of the load. Always use two leads to connect the load to the supply, regardless of where the setup is grounded. This will eliminate any possibility of output current return paths through the power source ground. The supply can also be operated up to 300Vdc above ground if neither output terminal is grounded.

3-21 OPERATION BEYOND RATED OUTPUT

3-22 The shaded areas on the front panel meter faces indicate the approximate amount of output voltage or current that may be available in excess of the normal rated output. Although the supply can be operated in these shaded regions without being damaged, it cannot be guaranteed to meet all of its performance specifications.

3-23 TRACKING OPERATION

3-24 When operated in the tracking mode (front-panel mode switch in TRACKING position), the instrument functions as a single power supply having equal magnitude positive and negative output voltages, both referred to a common bus. In this mode, the output of the right supply (slave) tracks the output of the left supply (master) to within 0.2% ± 2mV.

3-25 CONSTANT VOLTAGE

3-26 The VOLTAGE controls on the master supply set the output voltage of both the master and the

slave supplies in the tracking mode. The CURRENT controls of each supply act separately to set the current limit for each supply. When the instrument is used in the tracking mode, neither supply is capable of true constant current operation—the CURRENT controls set a gross current limit only. To select a constant voltage output, proceed as follows:

a. Set mode switch to TRACKING, connect jumper between negative output terminal of left supply and positive output terminal of right supply as shown on front panel, turn on power supply, and adjust left (master) VOLTAGE controls for desired output voltage on master and slave.

b. Short circuit each pair of output terminals and adjust each set of CURRENT controls for maximum output current allowable for each supply (current limit), as determined by load conditions. If a load change causes the current limit on the master to be exceeded, the supply will automatically cross over to current limited operation at the preset current limit and the master output voltage will drop proportionately. Note that since the slave will exactly follow every change in output voltage of the master, the slave voltage will also drop by the same amount. However, if a load change causes the current limit on the slave to be exceeded, the slave will automatically cross over into current limited operation (slave output voltage will drop proportionately) without having any effect on the master.

3-27 It must be understood that the slave will follow one-for-one every change in output voltage of the master. For example, if a load transient causes the master output volage to change, the same change will appear in the slave output voltage, even though there was no transient in the load connected to the slave, or even if there was no load connected to the slave at all. Similarly, any variation in programming speed, stability, or other master supply parameter will appear in the slave supply's output.

3-28 CONNECTING LOAD

3-29 Only the front output terminals can be used when the supply is in the tracking mode. Because sensing is accomplished at the front terminals when the supply is in the tracking mode, the supply will not meet the tracking or regulation specifications if loads are connected to the rear terminals.

CAUTION

Tracking operation is not possible with loads connected to the rear terminals. Do not switch from independent to tracking mode when loads are connected to the rear output terminals. Changing the mode switch position under these circumstances may result in damage to the switch.

3-30 For correct operation in the tracking mode, a jumper capable of carrying the full output current of the supply must be connected between the negative output terminal of the left supply and the positive output terminal of the right supply, as shown on the front panel. If this jumper is not connected when the instrument is used in the tracking mode, the supply will not meet its tracking specifications. In addition, the programming speed of the right supply (slave) will be much slower, and the supply may oscillate under certain load conditions.

3-31 The minus output terminal of the master (left) supply should be used as the common output terminal for the positive and negative output voltages. Using the slave positive terminal as the common terminal will result in regulation degradation due to the small but finite resistance of the wire connecting the two terminals. Each pair of loads should be connected to the power supply output terminals using separate sets of three wires. Each set of connecting wires should be as short as possible and twisted or shielded to reduce noise pickup. (If shielded three-conductor cable is used, connect the shield to ground at the power supply and leave the other end unconnected.)

3-32 If load considerations require that the output power distribution terminals be remotely located from the power supply, then the power supply output terminals should be connected to the remote distribution terminals via three twisted wires or a three-conductor shielded cable and each load should be separately connected to the remote distribution terminals. Note, however, that since remote sensing cannot be used when the instrument is operated in the tracking mode, the leads to the distribution terminals should be relatively short if degradation of the regulation specification is to be avoided.

3-33 Any one of the three output terminals (plus, minus, or common) can be grounded. However, three leads should always be used to connect the loads, regardless of where the setup is grounded. This will eliminate any possibility of output current return paths through the power source ground. If none of the output terminals are grounded, the two outputs can be floated at up to 300 volts total above ground.

3-34 The instrument will function as one power supply with twice the output voltage rating of one of the single supplies if no connection is made to the common terminal when operating in the tracking

mode (connect the load between the master positive terminal and the slave negative terminal). In this mode, the 6227B will supply 50 volts at 2 amps, and the 6228B will supply 100 volts at 1 amp. It is possible to set the meter switch on the master to volts and the meter switch on the slave to to amps and thereby achieve simultaneous monitoring of the output voltage and current. Note that in this configuration, the voltage reading on the master's meter must be doubled to give the actual output voltage.

3-35 OVERVOLTAGE CROWBAR OPERATION

3-36 The two crowbars are automatically connected for tandem operation when the mode switch is in the TRACKING position. In this operating mode, an overvoltage in either the master or the slave supply results in the firing of both crowbars.

3-37 The trip point of each crowbar may be independently adjusted by following the procedure in Paragraphs 3-13 and 3-14. Note however, that if an overvoltage transient causes one supply to crowbar (output voltage falls to one volt or less), the other supply will automatically crowbar, even though it did not experience an overvoltage transient. For example, if the slave crowbar is set for 10 volts and the master crowbar is set for 15 volts, the output of both supplies will fall to one volt or less if the slave output exceeds 10 volts.

3-38 Reset of the two crowbars is accomplished by following either of the two alternate procedures detailed in Paragraph 3-16. Turning the power switch off and on or turning the master voltage control down to zero and up again will reset both crowbars.

3-39 OPTIONAL OPERATING MODES (TRACKING OR INDEPENDENT)

3-40 The following optional operating modes describe methods of programming the constant voltage output(s) of the instrument in either the tracking or the independent mode of operation. When operating in the independent mode, the programming procedures can be applied to either or both of the independent supplies; when operating in the tracking mode, the procedures are to be applied to the master (left) supply only, since programming the master automatically programs the slave.

3-41 REMOTE PROGRAMMING, CONSTANT VOLTAGE

3-42 The constant voltage output of the power supply can be programmed (controlled) from a remote location if required. Either a resistance or voltage source can be used as the programming device. The wires connecting the programming terminals of the supply to the remote programming device should be twisted or shielded to reduce noise pickup. Note that although the programming sources are connected to the rear control terminals, the output must be taken from the front panel terminals when the supply is operated in the tracking mode. When the supplies are operated independently, the output may be taken from the rear terminals as shown in Figures 3-3 through 3-5. The VOLTAGE controls are automatically disabled in the following procedures.

3-43 Resistance Programming (Figure 3-3). In this mode, the output voltage will vary at a rate determined by the programming coefficient of 200 ohms/volt. The programming coefficient is determined by the programming current. This current is factory adjusted to within 10% of 5mA. If greater programming accuracy is required, it may be achieved by adjusting R16 as discussed in Paragraph 5-67.

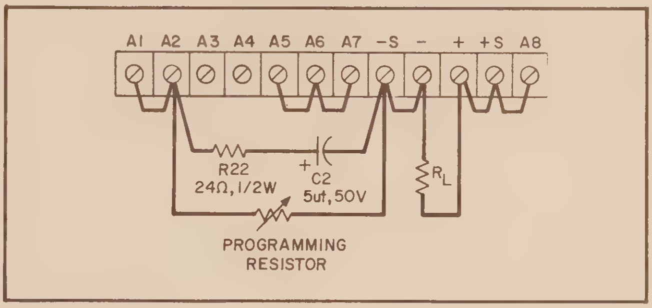


Figure 3-3. Remote Resistance Programming, Constant Voltage

3-44 When remote programmed in the tracking mode, the output voltage of each supply should be between zero and -60mV when zero ohms is connected across the master supply remote programming terminals. If the unit is operated in the independent mode, the master output voltage will be the same as above (between zero and -60mV) when zero ohms is connected across the master supply remote programming terminals, while the slave output voltage will be 0 ± 10mV when zero ohms is connected across its remote programming terminals. The output voltage of each supply may be adjusted to exactly zero under any of the above conditions by adjusting potentiometer R24 on each supply as described in Paragraph 5-65.

3-45 To maintain the stability and temperature coefficient of the power supply, use programming resistors that have stable, low noise, and low temperature coefficient (less than 20ppm per degree Centigrade) characteristics. Resistor-capacitor combination R22-C2 should be connected across the programming terminals as shown in Figure 3-3; these components reduce ripple in the supply

output. A switch can be used in conjunction with various resistance values in order to obtain discrete output voltages. The switch should have make-before-break contacts to avoid momentarily opening the programming terminals during the switching interval.

3-46 Voltage Programming, Unity Gain (Figure 3-4). Employ the strapping pattern shown in Figure 3-4 for voltage programming with unity gain. In this mode, the output voltage will vary in a 1 to 1 ratio with the programming voltage (reference voltage) and the load on the programming voltage source will not exceed 20μA. Impedance matching resistor (R_X) is required to maintain the temperature coefficient and stability specifications of the supply; resistor-capacitor combination R22-C2 is required to reduce ripple in the supply output.

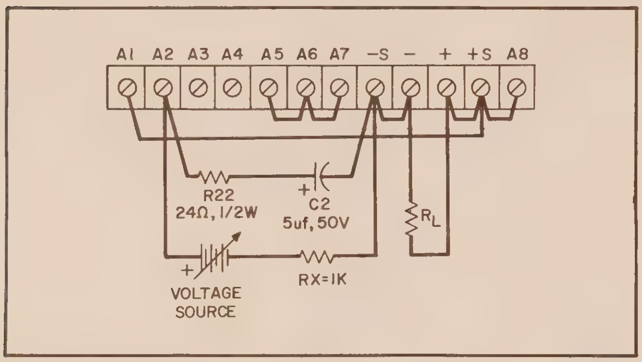


Figure 3-4. Remote Voltage Programming, Constant Voltage (Unity Gain)

3-47 Voltage Programming, Variable Gain (Figure 3-5). The strapping pattern shown in Figure 3-5 can be utilized for programming the power supply with variable voltage gain using an external voltage source. The output voltage in this configuration is found by multiplying the external voltage source by (R_P/R_R).

3-48 External resistors R_P and R_R should have stable, low noise, and low temperature coefficient (less than 20ppm per degree Centigrade) characteristics in order to maintain the supply's temperature and stability specifications. The values of reference resistor R_R and programming voltage source V_S should be such that the value of V_S/R_R is equal to or greater than 5mA. The value of resistor R_R should not exceed 10KΩ; the power rating of resistor R_R should be at least 10 times the actual power dissipated in the resistor. Resistor-capacitor combination R22-C2 should be connected across the programming terminals as shown in Figure 3-5; these components reduce ripple in the supply output. Note that it is possible to use the front panel voltage control already in the supply (R27A-R27B) as the voltage gain control (R_P) by simply removing the external R_P and strapping terminals A2 and A3 together.

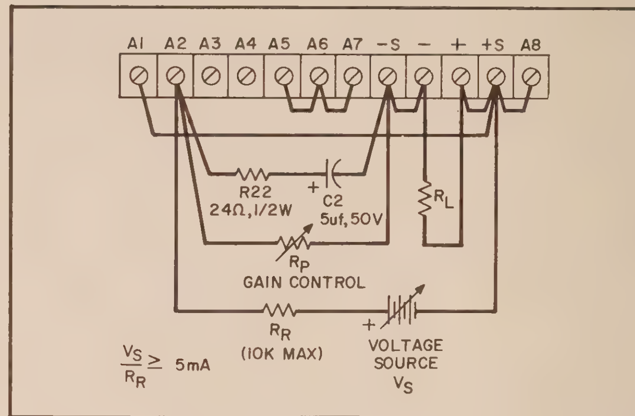


Figure 3-5. Remote Voltage Programming, Constant Voltage (Variable Gain)

3-49 The output voltage of the supply may be adjusted to exactly zero when the external programming voltage is zero by adjusting potentiometer R24 as discussed in Paragraph 5-65.

3-50 OPTIONAL OPERATING MODES (INDEPENDENT ONLY)

3-51 The following optional programming modes describe methods of (1) programming the constant current outputs, (2) remote sensing, and (3) connecting several supplies in auto-series, auto-parallel, or auto-tracking arrangements. These procedures are for use when the instrument is operated in the independent mode only; they cannot be used when the supply is operated in the tracking mode.

3-52 REMOTE PROGRAMMING, CONSTANT CURRENT

3-53 Either a resistance or a voltage source can be used to control the constant current output of the supply. The CURRENT controls on the front panel are automatically disabled in the following procedures.

3-54 Resistance Programming (Figure 3-6). In this mode, the output current varies at a rate determined by the programming coefficient as follows:

Model	Programming Coefficient
6227B	500 ohms/ampere
6228B	1,000 ohms/ampere

The programming coefficient is determined by the constant current programming current which is adjusted to within 10% of 1mA at the factory. If greater programming accuracy is required, it may be achieved by adjusting R2 as discussed in

Paragraph 5-71. The output current of the supply when zero ohms is placed across the programming terminals may be set to exactly zero by adjusting R7 as discussed in Paragraph 5-69.

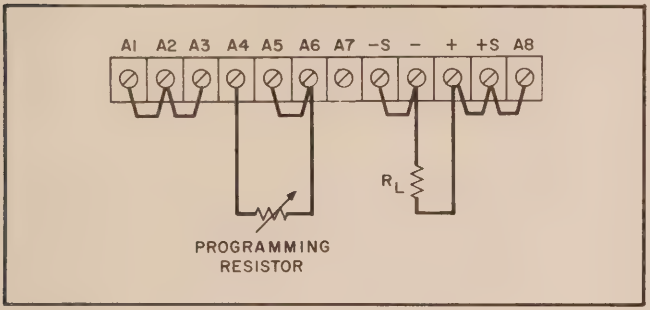


Figure 3-6. Remote Resistance Programming, Constant Current

3-55 Use stable, low noise, low temperature coefficient (less than 20ppm per degree Centigrade) programming resistors to maintain the power supply temperature coefficient and stability specifications. A switch may be used to set discrete values of output current. A make-before-break type of switch should be used since the output current will exceed the maximum rating of the power supply if the switch contacts open during the switching interval.

CAUTION

If the programming terminals (A4 and A6) should open at any time during the remote resistance programming mode, the output current will rise to a value that may damage the power supply and/or the load. If, in the particular programming configuration in use, there is a chance that the terminals might become open, it is suggested that a 1.1KΩ resistor be connected across the programming terminals. Like the programming resistor, this resistor should be a low noise, low temperature coefficient type. Note that when this resistor is used, the resistance value actually programming the supply is the parallel combination of the remote programming resistance and the resistor across the programming terminals.

3-56 Voltage Programming, Unity Gain (Figure 3-7). In this mode, the output current will vary linearly with changes in the programming voltage. The programming voltage should not exceed 1.1 volt. Voltage in excess of 1.1 volt will result in excessive power dissipation in the instrument and possible damage.

3-57 The output current varies at a rate determined by the programming coefficient as follows:

Model	Programming Coefficient
6227B	0.5 volts/ampere
6228B	1.0 volts/ampere

The current required from the voltage source will be less than 20μA. Impedance matching resistor R_X is required to maintain the temperature coefficient and stability specifications of the supply.

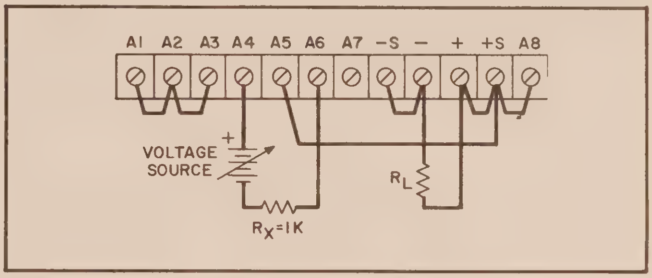


Figure 3-7. Remote Voltage Programming, Constant Current (Unity Gain)

3-58 Voltage Programming, Variable Gain (Figure 3-8). The power supply output current can be programmed with variable gain using an external voltage source by utilizing the strapping pattern shown in Figure 3-8. In this mode, the output current is found by multiplying the external voltage source (V_S) by $[R_P/(R_R \times K_P)]$, where K_P is the constant current voltage programming coefficient as given in Paragraph 3-57.

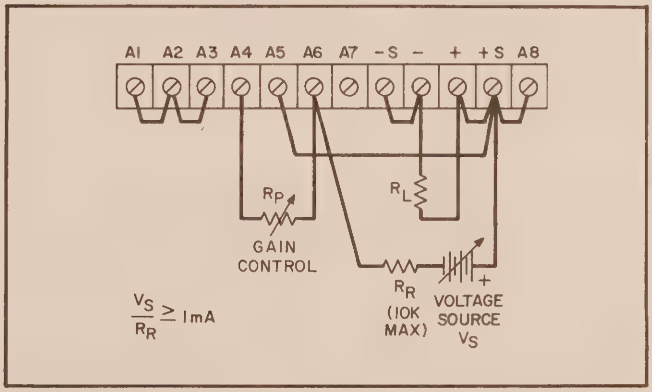


Figure 3-8. Remote Voltage Programming, Constant Current (Variable Gain)

3-59 External resistors R_P and R_R should have stable, low noise, and low temperature coefficient (less than 20ppm per degree Centigrade)

characteristics in order to maintain the stability and temperature specifications of the power supply. The values of reference resistor R_R and programming voltage source V_S should be such that the value of V_S/R_R is equal to or greater than 1mA. The value of resistor R_R should not exceed 10KΩ; the power rating of resistor R_R should be at least 10 times the actual power dissipated in the resistor. Note that it is possible to use the front panel current control already in the supply (R4) as the gain control (R_P) by simply removing the external R_P and strapping terminals A6 and A7 together.

3-60 The output current of the supply may be adjusted to exactly zero when the external programming voltage is zero by adjusting resistor R7 as discussed in Paragraph 5-69.

3-61 REMOTE SENSING (Figure 3-9)

3-62 Remote sensing is used to maintain good regulation at the load and reduce the degradation of regulation which would occur due to the voltage drop in the leads between the power supply and the load. Remote sensing is accomplished by utilizing the strapping pattern shown in Figure 3-9. Note that terminal A8 should be connected to the (+) terminal rather than +S. The power supply should be turned off before changing strapping patterns. The leads from the sensing (±S) terminals to the load will carry much less current than the load leads and it is not required that these leads be as heavy as the load leads. However, they must be twisted or shielded to minimize noise pickup.

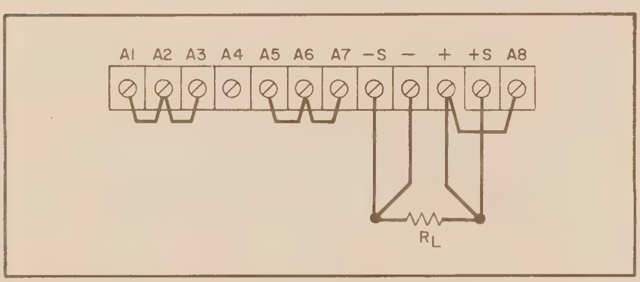


Figure 3-9. Remote Sensing

3-63 For reasonable load lead lengths, remote sensing greatly improves the performance of the supply. However, if the load is located a considerable distance from the supply, added precautions must be observed to obtain satisfactory operation. Notice that the voltage drop in the load leads subtracts directly from the available output voltage and also reduces the amplitude of the feedback error signals that are developed within the unit. Because of these factors it is recommended that the drop in each load lead not exceed 0.5 volt. If a larger drop must be tolerated, please consult an HP Sales Engineer.

NOTE

Due to the voltage drop in the load leads, it may be necessary to readjust the current limit in the remote sensing mode.

3-64 Observance of the precautions in Paragraph 3-63 will result in a low dc output impedance at the load. However, another factor that must be considered is the inductance of long load leads. this causes a high ac impedance and could affect the stability of the feedback loop seriously enough to cause oscillation. In this case, it is recommended that the following precautions be taken:

a. Disconnect output capacitor C1 by unstrapping terminal A8.

b. Connect a capacitor having similar characteristics (approximately the same capacitance, the same voltage rating or greater, and having good high frequency characteristics) across the load using short leads.

3-65 Although the strapping patterns shown in Figure 3-3 through 3-8 employ local sensing, note that it is possible to operate a power supply simultaneously in the remote sensing and constant voltage/constant current remote programming modes.

3-66 AUTO-PARALLEL OPERATION (Figure 3-10)

3-67 Two or more power supplies can be connected in an Auto-Parallel arrangement to obtain an output current greater than that available from one supply. Auto-Parallel operation permits equal current sharing under all load conditions, and allows complete control of the output current from one master power supply. The output current of each slave will be approximately equal to the master's output current regardless of the load conditions. Because the output current controls of each slave are operative, they should be set to maximum to prevent the slave reverting to constant current operation; this could occur if the master output current setting exceeded the slave's.

3-68 Additional slave supplies may be added in parallel with the master/slave combination. All the connections between the master and slave #1 are duplicated between slave #1 and the added slave supply. In addition, the strapping pattern of the added slave should be the same as slave #1. Remote sensing and programming can be used, though the strapping arrangements shown in Figure 3-10 show local sensing and programming. In order to maintain the temperature coefficient and

stability specifications of the power supply, the external resistors (R_X) should be stable, low noise, low temperature coefficient (less than 20ppm per degree Centigrade) resistors. The power rating of R_X should be at least 10 times the actual power dissipated in the resistor.

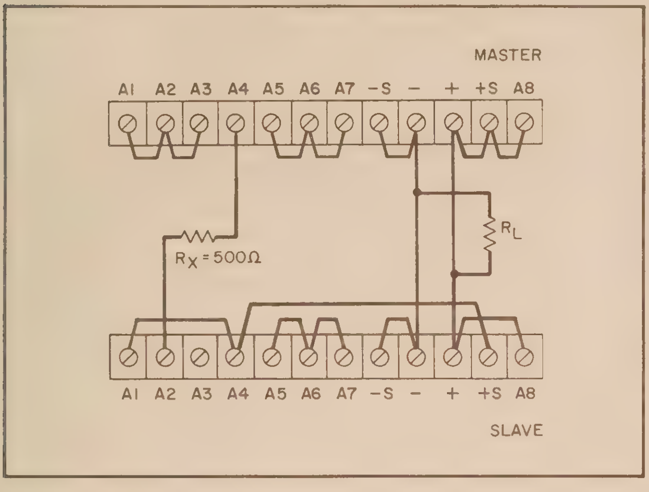


Figure 3-10. Auto-Parallel Operation, Two Units

3-69 The overvoltage crowbar circuit in each supply operates independently; no provision is included for allowing the master crowbar to trigger the slave crowbar. However, since the supplies are in parallel, the crowbars are effectively in parallel, and if one crowbar fires, it will by necessity short out both supplies. Thus it is only necessary to set one CROWBAR ADJUST control; the other control can be turned fully clockwise.

3-70 AUTO-SERIES OPERATION (Figure 3-11)

3-71 Two or more power supplies can be operated in Auto-Series to obtain a higher voltage than that available from a single supply. When this connection is used, the output voltage of each slave supply varies in accordance with that of the master supply; thus the total output voltage of the combination is determined by the setting of the front panel VOLTAGE controls on the master. The master supply must be the most positive supply of the series. The output CURRENT controls of all series units are operative and the current limit is equal to the lowest control setting. If any of the output CURRENT controls are set too low, automatic crossover to constant current operation will occur and the output voltage will drop. Remote sensing and programming can be used, though the strapping arrangements shown in Figure 3-11 show local sensing and programming.

3-72 In order to maintain the temperature coefficient and stability specifications of the power supply, the external resistors (R_X) shown in Figure 3-11 should be stable, low noise, low temperature coefficient (less than 20ppm per degree Centigrade) resistors. The value of R_X is the maximum voltage rating of the master supply divided by the voltage programming current of the slave supply ($1/K_P$ where K_P is the voltage programming coefficient). The power rating of R_X should be at least 10 times the actual power dissipated in the resistor. The voltage contribution of the slave is determined by its voltage control setting.

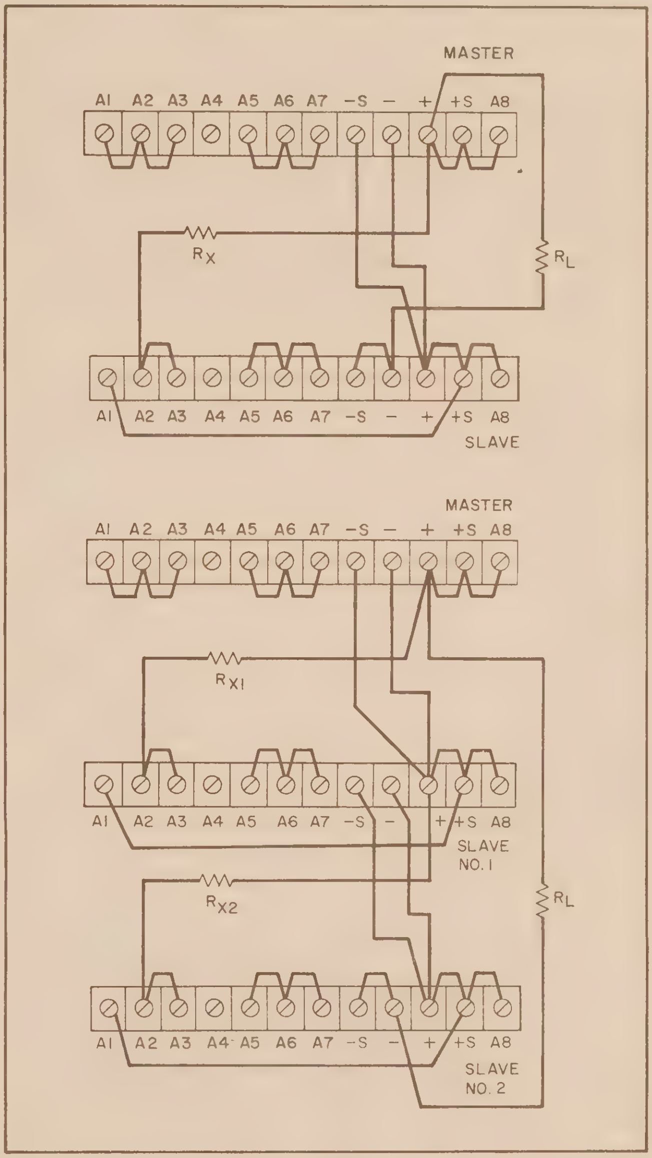


Figure 3-11. Auto-Series Operation, Two and Three Units

3-73 The overvoltage crowbar circuit in each supply operates independently; no provision is included for allowing the master crowbar to trigger the slave crowbar. The CROWBAR ADJUST

potentiometer in each supply should be adjusted so that it trips at a point slightly above the output voltage that the supply will contribute. Note that since a portion of the master supply acts as the reference that sets the output level of the slave, if the master supply crowbars, the total output voltage of the combination will drop to approximately zero. However, the reverse is not true—if the slave crowbar trips, the total output voltage of the combination will drop only to the level of the master supply.

3-74 AUTO-TRACKING OPERATION (Figure 3-12)

3-75 The Auto-Tracking configuration is used when several different voltages referred to a common bus must vary in proportion to the setting of a particular instrument (the control or master). A fraction of the master's output voltage is fed to the comparison amplifier of the slave supply, thus controlling the slave's output. The master must have the largest output voltage of any power supply in the group. It must be the most positive supply in the example shown in Figure 3-12.

3-76 The output voltage of the slave (E_S) is a percentage of the master's output voltage (E_M), and is determined by the voltage divider consisting of R_X and the voltage control of the slave supply, R_P, where $E_S = E_M \left[R_P/(R_X + R_P)\right]$. Remote sensing and programming can be used (each supply senses at its own load), though the strapping patterns given in Figure 3-12 show only local sensing and programming. In order to maintain the temperature coefficient and stability specifications of the power supply, the external resistors (R_X) should be stable, low noise, low temperature coefficient (less than 20ppm/^{o}C) resistors. The value of R_X is found by multiplying the voltage programming coefficient of the slave supply by the desired difference between the master supply voltage and the slave supply voltage.

3-77 The overvoltage crowbar circuit in each unit is operable and independently monitors the voltage across its own load. Notice that if the master supply crowbars, the output voltage of each slave will also fall to approximately zero. However, the reverse is not true. If one of the slave units crowbars, the other supplies in the ensemble will not be affected.

3-78 SPECIAL OPERATING CONSIDERATIONS

3-79 PULSE LOADING

3-80 The power supply will automatically cross over from constant voltage to constant current operation, or the reverse, in response to an increase (over the preset limit) in the output current or voltage, respectively. Although the preset limit may be set higher than the average output current or voltage, high peak currents or voltages (as occur in pulse loading) may exceed the preset limit and cause crossover to occur. If this crossover limiting is not desired, set the preset limit for the peak requirement and not the average.

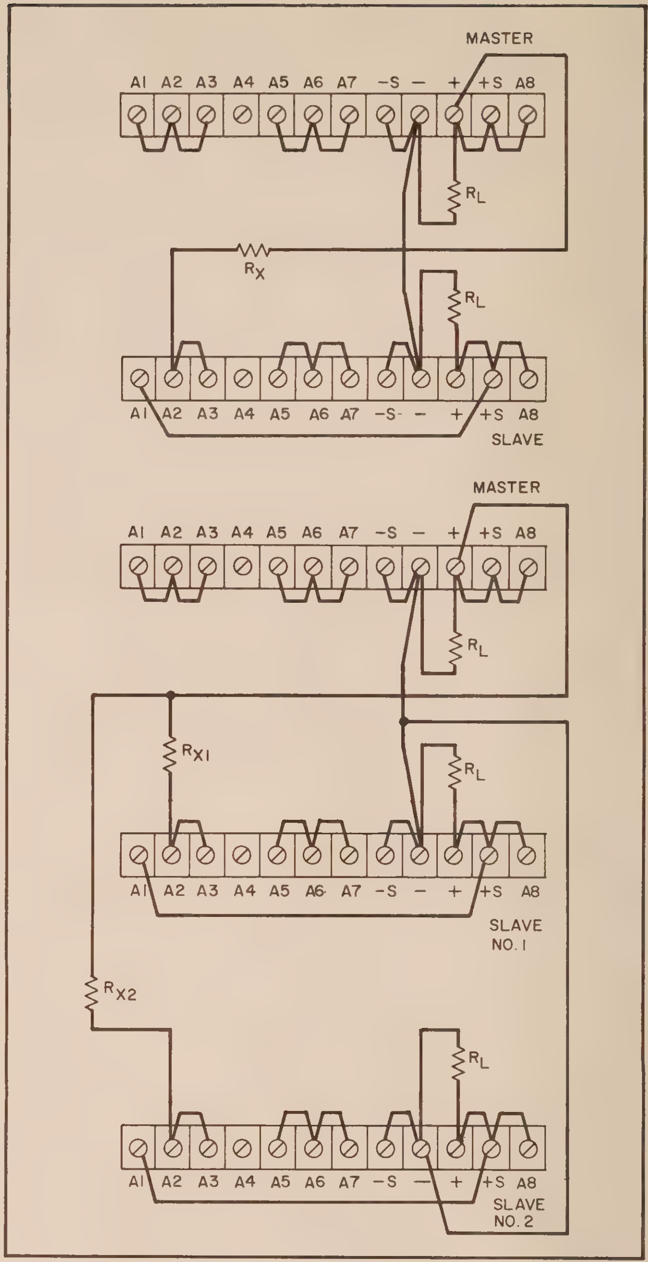


Figure 3-12. Auto-Tracking Operation, Two and Three Units

3-81 OUTPUT CAPACITANCE

3-82 An internal capacitor (C1) connected across the output terminals of the power supply, helps to supply high-current pulses of short duration during constant voltage operation. To reduce current

surges, this capacitor can be removed by unstrapping terminal A8. Any capacitance added externally will improve the pulse current capability, but will decrease the safety provided by the constant current circuit. A high-current pulse may damage load components before the average output current is large enough to cause the constant current circuit to operate.

3-83 The effects of the output capacitor during constant current operation are as follows:

a. The output impedance of the power supply decreases with increasing frequency.

b. The recovery time of the output voltage is longer for load resistance changes.

c. A large surge current causing a high power dissipation in the load occurs when the load resistance is reduced rapidly.

3-84 REVERSE VOLTAGE LOADING

3-85 A diode (CR2) is connected across the output terminals. Under normal operating conditions, the diode is reverse biased (anode connected to the negative terminal). If a reverse voltage is applied to the output terminals (positive voltage applied to the negative terminal), the diode will conduct, shunting current across the output terminals and limiting the voltage applied across the output terminals to the forward voltage drop of the diode. This diode protects the series transistors and the output electrolytic capacitors.

3-86 REVERSE CURRENT LOADING

3-87 Active loads connected to the power supply may actually deliver a reverse current to the power supply during a portion of its operating cycle. An external source cannot be allowed to pump current into the supply without loss of regulation and possible damage to the output capacitor. To avoid these effects, it is necessary to preload the supply with a dummy load resistor so that the power supply delivers current through the entire operation cycle of the load device.

SECTION IV
PRINCIPLES OF OPERATION

(To Be Supplied With Final Manual)

SECTION V
MAINTENANCE

5-1 INTRODUCTION

5-2 Upon receipt of the power supply, the performance check (Paragraph 5-5) should be made. This check is suitable for incoming inspection. If a fault is detected in the power supply while making the performance check or during normal operation, proceed to the troubleshooting procedures (Paragraph 5-). After troubleshooting and repair (Paragraph 5-), perform any necessary adjustments and calibrations (Paragraph 5-56). Before returning the power supply to normal operation, repeat the performance check to ensure that the fault has been properly corrected and that no other faults exist. Before performing any maintenance checks, turn on the power supply and allow a half-hour warm-up.

5-3 TEST EQUIPMENT REQUIRED

5-4 Table 5-1 lists the test equipment required to perform the various procedures described in this section.

Table 5-1. Test Equipment Required

TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
Differential Voltmeter	Sensitivity: 500µV full scale (min.). Input impedance: 10MΩ (min.).	Measure dc voltages; calibration procedures.	HP 3420B (See Note on Page 5-2.)
Oscilloscope	Sensitivity and bandwidth: 50µV/cm and 300kHz for all measurements except noise spike; 1mV and 20MHz for noise spike measurement.	Measure ripple; display transient recovery waveforms; measure noise spikes.	HP 140A with 1403A vertical plug-in and 1423A time base; HP 180A with 1803A vertical plug-in and 1820A time base for spike measurement.
DC Voltmeter	Sensitivity: 1mV full scale (min.). Accuracy: 1%.	Measure dc voltages.	HP 412A.
AC Voltmeter	Sensitivity: 50µV full scale (min.). Frequency range: 5Hz to 250kHz (min.). Accuracy: 3%.	Measure output impedance, ripple, and ac voltages.	HP 3410A.
Oscillator	Frequency range: 5Hz to 20kHz (min.). Output: 5V rms into 600Ω. Accuracy: 3%.	Measure output impedance.	HP 209A.
Amplifier	Power output: 50 watts. Frequency response: ±3dB 5Hz to 20kHz (min.).	Measure output impedance.	HP 6824A.

Table 5-1. Test Equipment Required (Continued)

TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
Variable Voltage Transformer	Range: 103 to 127Vac. Recommended minimum output current: 5.5A.	Vary ac input for line regulation measurement.	---
Repetitive Load Switch	Switching rate: 60 to 400Hz. Rise time: 2μsec.	Measure transient recovery time.	See Figure 5-5.
Resistive Loads	Values: See Figures 5-2 and 5-11.	Power supply load resistors.	---
Current Sampling Resistors	Values: See Figures 5-7 and 5-11.	Measure output impedance; measure output current; calibrate ammeter.	R10 and R11 (6227B); R10 (6228B); see Replaceable Parts List.
Terminating Resistors	Value: 50 ohms, $\frac{1}{2}$ watt, ±5%, non-inductive, 4 required.	Noise spike measurement.	---
Blocking Capacitors	Values: 0.01μF, 100Vdc, 2 required; 1000μF, 60Vdc, 1 required.	Noise spike measurement; output impedance measurement.	---

NOTE

A satisfactory substitute for a differential voltmeter is a reference voltage source and null detector arranged as shown in Figure 5-1. The reference voltage source is adjusted so that the voltage difference between the supply being measured and the reference voltage will have the required resolution for the measurement being made. The voltage difference will be a function of the null detector that is used. Examples of satisfactory null detectors are: HP 419A null detector, a dc coupled oscilloscope utilizing differential input, or a 10 mV meter movement with a 100 division scale. For the latter, a 0.5mV change in voltage will result in a meter deflection of five divisions.

CAUTION

Care must be exercised to avoid ground loops and circulating currents when using an electronic null detector in which one input terminal is grounded.

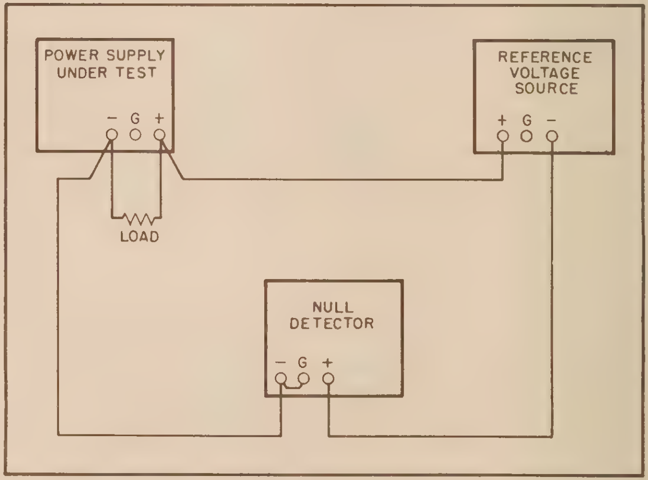


Figure 5-1. Differential Voltmeter Substitute Test Setup

5-5 PERFORMANCE TEST

5-6 The following test can be used as an incoming inspection check and appropriate portions of the test can be repeated either to check the operation of the instrument after repairs or for periodic maintenance tests. The tests are performed using a 115V ac, 60Hz, single phase input power source.

With the exception of the tracking specification test (refer to Paragraph 5-42), all of the following measurements should be made on both of the independent power supplies contained in the instrument. If the correct result is not obtained for a particular check, do not adjust any internal controls; proceed to troubleshooting (Paragraph 5-).

5-7 CONSTANT VOLTAGE TESTS

5-8 All measuring devices must be connected to the rear output terminals of the supply and not to the front terminals (with the exception of the tracking specification, as noted in Paragraph 5-42), if maximum accuracy is to be obtained in the following measurements. In addition, the measuring devices must be connected as close to the output terminals as possible. This is particularly important when measuring the transient response, regulation, or ripple of the power supply. A measurement made across the load includes the impedance of the leads to the load and such lead lengths can easily have an impedance several orders of magnitude greater than the supply impedance, thus invalidating the measurement.

5-9 To avoid mutual coupling effects, each monitoring device must be connected to the output terminals by a separate pair of leads. Twisted pairs or shielded two-wire cables should be used to avoid pickup on the measuring leads. The load resistor should be connected across the output terminals as close to the supply as possible. When measuring the constant voltage performance specifications, the current controls should be set well above (at least 10%) the maximum output current which the supply will draw, since the onset of constant current action will cause a drop in output voltage, increased ripple, and other performance changes not properly ascribed to the constant voltage operation of the supply.

5-10 Voltage Output and Voltmeter Accuracy. To check the output voltage, proceed as follows:

a. Connect load resistor (R_L) indicated in Figure 5-2 across output terminals of supply.

b. Connect differential voltmeter across +OUT and -OUT terminals of supply, observing correct polarity.

c. Turn CURRENT controls fully clockwise.

d. Turn on supply and adjust VOLTAGE controls until front panel meter indicates exactly maximum rated output voltage.

e. Differential voltmeter should indicate the following:

6227B 25 ± 0.6Vdc
6228B 50 ± 1.2Vdc

5-11 Load Regulation.

Definition: The change ΔE_{OUT} in the static value of dc output voltage resulting from a change in load resistance from open circuit to a value which yields maximum rated output current (or vice versa).

5-12 To check the constant voltage load regulation, proceed as follows:

a. Connect test setup shown in Figure 5-2.

b. Turn CURRENT controls fully clockwise.

c. Turn on supply and adjust VOLTAGE controls until front panel meter indicates exactly maximum rated output current.

d. Read and record voltage indicated on differential voltmeter.

e. Disconnect load resistor.

f. Reading on differential voltmeter should not vary from reading recorded in Step (d) by more than the following:

6227B 3.5mV
6228B 6.0mV

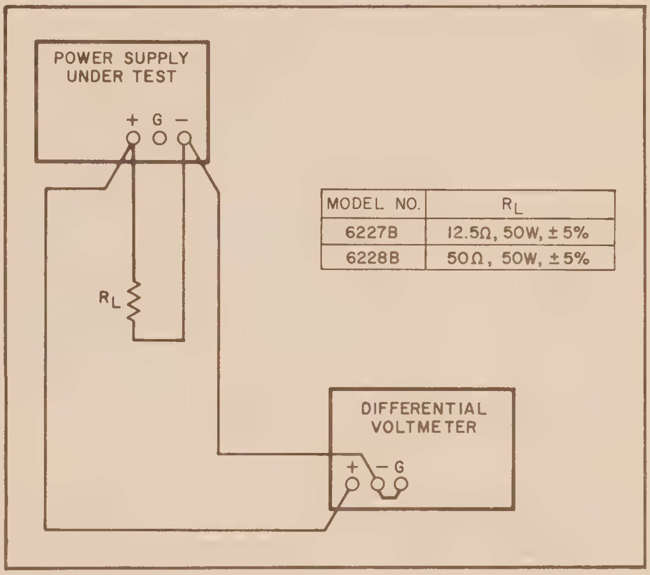


Figure 5-2. Constant Voltage Load Regulation Test Setup

5-13 Line Regulation.

Definition: The change ΔE_{OUT} in the static value of dc output voltage resulting from a change in ac input voltage over the specified range from low line (usually 103.5 volts) to high line (usually 126.5 volts), or from high line to low line.

5-14 To check the line regulation, proceed as follows:

a. Connect test setup shown in Figure 5-2.

b. Connect variable auto transformer

between input power source and power supply power input.

c. Adjust variable auto transformer for 103.5 volts ac input.

d. Turn CURRENT controls fully clockwise.

e. Turn on supply and adjust VOLTAGE controls until front panel meter indicates exactly maximum rated output voltage.

f. Read and record voltage indicated on differential voltmeter.

g. Adjust variable auto transformer for 126.5 volts ac input.

h. Reading on differential voltmeter should not vary from reading recorded in Step (f) by more than 1mV.

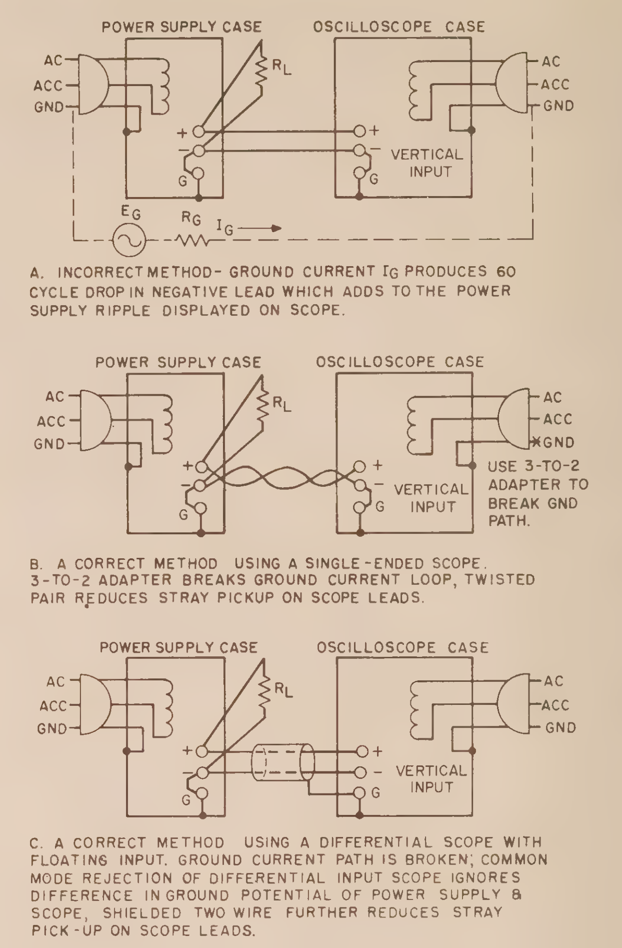
5-15 Ripple and Noise.

Definition: The residual ac voltage superimposed on the dc output of a regulated power supply. Ripple and noise may be specified and measured in terms of its RMS or (preferably) peak-to-peak value.

Ripple and noise measurement can be made at any input ac line voltage combined with any dc output voltage and load current within the supply's rating.

5-16 The amount of ripple and noise that is present in the power supply output is measured either in terms of the RMS or (preferably) peak-to-peak value. The peak-to-peak measurement is particularly important for applications where noise spikes could be detrimental to a sensitive load, such as logic circuitry. The RMS measurement is not an ideal representation of the noise, since fairly high output noise spikes of short duration can be present in the ripple without appreciably increasing the RMS value.

5-17 Ripple Measurements. Figure 5-3A shows an incorrect method of measuring p-p ripple. Note that a continuous ground loop exists from the third wire of the input power cord of the supply to the third wire of the input power cord of the oscilloscope via the grounded power supply case, the wire between the negative output terminal of the power supply and the vertical input of the scope, and the grounded scope case. Any ground current circulating in this loop as a result of the difference in potential E_G between the two ground points causes an IR drop which is in series with the scope input. This IR drop, normally having a 60Hz line frequency fundamental, plus any pickup on the unshielded leads interconnecting the power supply and scope, appears on the face of the CRT. The magnitude of this resulting noise signal can easily be much greater than the true ripple developed between the plus and minus output terminals of the power supply, and can completely invalidate the measurement.



MODEL NO.	R_L
6227B	12.5Ω, 50W, ±5%
6228B	50Ω, 50W, ±5%

Figure 5-3. Ripple Test Setup

5-18 The same ground current and pickup problems can exist if an RMS voltmeter is substituted in place of the oscilloscope in Figure 5-3. However, the oscilloscope display, unlike the true RMS meter reading, tells the observer immediately whether the fundamental period of the signal displayed is 8.3 milliseconds (1/120Hz) or 16.7 milliseconds (1/60Hz). Since the fundamental ripple frequency present on the output of an HP supply is 120Hz (due to full-wave rectification), an oscilloscope display showing a 120Hz fundamental component is indicative of a "clean" measurement setup, while the presence of a 60Hz fundamental usually means that an improved setup will result in a more accurate (and lower) value of measured ripple.

5-19 Figure 5-3B shows a correct method of

measuring the output ripple of a constant voltage power supply using a single-ended scope. The ground loop path is broken with a 3-to-2 adapter in series with the oscilloscope's ac line plug. Notice, however, that the oscilloscope case is still connected to ground via the scope output terminals, the leads connecting these terminals to the power supply terminals, the power supply case and the third wire of the power supply line cord.

5-20 Either a twisted pair or (preferably) a shielded two-wire cable should be used to connect the output terminals of the power supply to the vertical input terminals of the scope. When using a twisted pair, care must be taken that one of the two wires is connected both to the grounded terminal of the power supply and the grounded input terminal of the oscilloscope. When using shielded two-wire cable, it is essential for the shield to be connected to ground at one end only to prevent any ground current flowing through this shield from inducing a signal in the shielded leads.

5-21 To verify that the oscilloscope is not displaying ripple that is induced in the leads or picked up from the grounds, the (+) scope lead should be shorted to the (-) scope lead at the power supply terminals. The ripple value obtained when the leads are shorted should be subtracted from the actual ripple measurement.

5-22 In most cases, the single-ended scope method of Figure 5-3B will be adequate to eliminate non-real components of ripple so that a satisfactory measurement may be obtained. However, in more stubborn cases or in measurement situations where it is essential that both the power supply case and the oscilloscope case be connected directly to ground (e.g. if both are rack-mounted), it may be necessary to use a differential scope with floating input as shown in Figure 5-3C. If desired, two single-conductor shielded cables may be substituted in place of the shielded two-wire cable with equal success. Because of its common mode rejection, a differential oscilloscope displays only the difference in signal between its two vertical input terminals, thus ignoring the effects of any common mode signal produced by the difference in the ac potential between the power supply case and scope case. Before using a differential input scope in this manner, however, it is imperative that the common mode rejection capability of the scope be verified by shorting together its two input leads at the power supply and observing the trace on the CRT. If this trace is a straight line, then the scope is properly ignoring any common mode signal present. If this trace is not a straight line, then the scope is not rejecting the ground signal and must be realigned in accordance with the manufacturer's instructions until proper common mode rejection is attained.

5-23 To check the ripple output, proceed as follows:

a. Connect oscilloscope or RMS voltmeter as shown in Figures 5-3B or 5-3C.

b. Turn CURRENT controls fully clockwise.

c. Adjust VOLTAGE controls until front panel meter indicates maximum rated output voltage.

d. The observed ripple should be less than 250µVrms and 4mV p-p.

5-24 Noise Spike Measurement. When a high frequency spike measurement is being made, an instrument of sufficient bandwidth must be used; an oscilloscope with a bandwidth of 20MHz or more is adequate. Measuring noise with an instrument that has insufficient bandwidth may conceal high frequency spikes detrimental to the load.

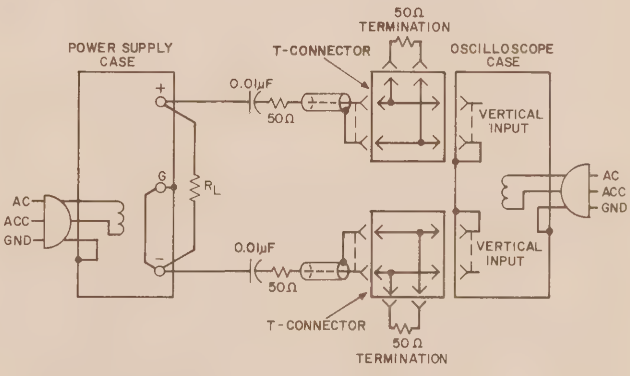
5-25 The test setups illustrated in Figure 5-3A and 5-3B are generally not acceptable for measuring spikes; a differential oscilloscope is necessary. Furthermore, the measurement concept of Figure 5-3C must be modified if accurate spike measurement is to be achieved:

1. As shown in Figure 5-4, two coax cables must be substituted for the shielded two-wire cable.

2. Impedance matching resistors must be included to eliminate standing waves and cable ringing, and capacitors must be inserted to block the dc current path.

3. The length of the test leads outside the coax is critical and must be kept as short as possible; the blocking capacitor and the impedance matching resistor should be connected directly from the inner conductor of the cable to the power supply terminals.

4. Notice that the shields of the power supply end of the two coax cables are not connected



MODEL NO.	R_L
6227B	12.5Ω, 50W, ± 5%
6228B	50Ω, 50W, ± 5%

Figure 5-4. Noise Spike Measurement Test Setup

to the power supply ground, since such a connection would give rise to a ground current path through the coax shield, resulting in an erroneous measurement.

5. Since the impedance matching resistors constitute a 2-to-1 attenuator, the noise spikes observed on the oscilloscope should be less than 2mV p-p instead of 4mV p-p.

5-26 The setup of Figure 5-4 can also be used for the normal measurement of low frequency ripple; simply remove the four terminating resistors and the blocking capacitors and substitute a higher gain vertical plug-in in place of the wide-band plug-in required for spike measurements. Notice that with these changes, Figure 5-4 becomes a two-cable version of Figure 5-3C.

5-27 Transient Recovery Time.

Definition: The time "X" for the output voltage recovery to within "Y" millivolts of the nominal output voltage following a "Z" amp step change in load current, where: "Y" is specified as 10mV, the nominal output voltage is defined as the dc level halfway between the static output voltage before and after the imposed load change, and "Z" is the specified load current change of 5 amps or the full load current rating of the supply, whichever is less.

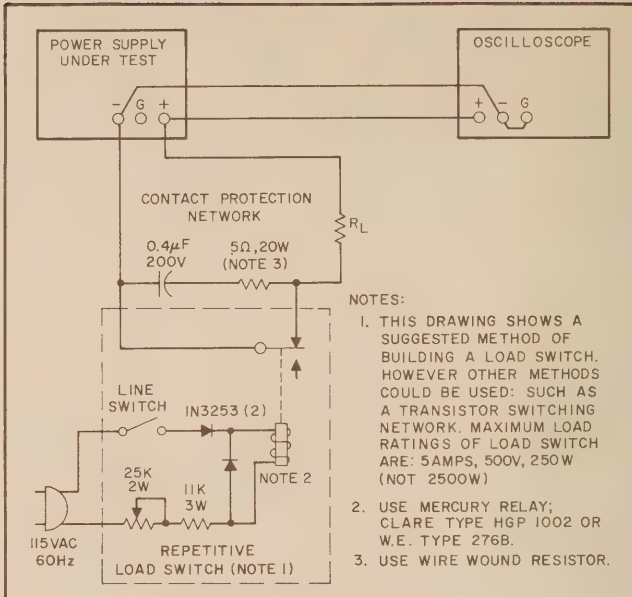
5-28 Transient recovery time may be measured at any input line voltage combined with any output voltage and load current within rating.

5-29 Reasonable care must be taken in switching the load resistance on and off. A hand-operated switch in series with the load is not adequate, since the resulting one-shot displays are difficult to observe on most oscilloscopes, and the arc energy occurring during switching action completely masks the display with a noise burst. Transistor load switching devices are expensive if reasonably rapid load current changes are to be achieved.

5-30 A mercury-wetted relay, as connected in the load switching circuit of Figure 5-5 should be used for loading and unloading the supply. When this load switch is connected to a 60Hz ac input, the mercury-wetted relay will open and close 60 times per second. Adjustment of the 25K control permits adjustment of the duty cycle of the load current switching and reduction in jitter of the oscilloscope display.

5-31 To check the transient recovery time, proceed as follows:

a. Connect test setup shown in Figure 5-5.
b. Turn CURRENT controls fully clockwise.



MODEL NO.	R_L
6227B	12.5Ω, 50W, ±5%
6228B	50Ω, 50W, ±5%

Figure 5-5. Transient Recovery Time Test Setup

c. Turn on supply and adjust VOLTAGE controls until front panel ammeter indicates maximum rated output current.

d. Close line switch on repetitive load switch setup.

e. Set oscilloscope for internal sync and lock on either positive or negative load transient spike.

f. Set vertical input of oscilloscope for ac coupling so that small dc level changes in power supply output voltage will not cause display to shift.

g. Adjust the vertical centering on the scope so that the tail ends of the no load and full load waveforms are symmetrically displayed about the horizontal center line of the oscilloscope. This center line now represents the nominal output voltage defined in the specification.

h. Adjust the horizontal positioning control so that the trace starts at a point coincident with a major graticule division. This point is then representative of time zero.

i. Increase the sweep rate so that a single transient spike can be examined in detail.

j. Adjust the sync controls separately for the positive and negative going transients so that not only the recovery waveshape but also as much as possible of the rise time of the transient is displayed.

k. Starting from the major graticule division representative of time zero, count to the right 50μsec and vertically 10mV. Recovery should be within these tolerances as illustrated in Figure 5-6.

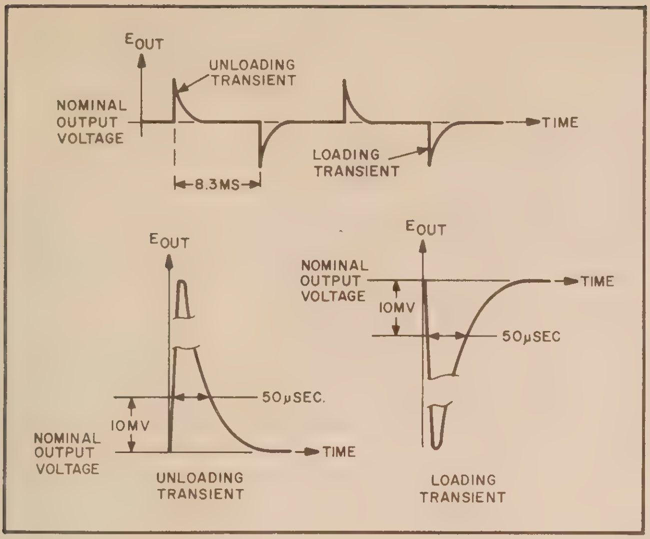


Figure 5-6. Transient Recovery Time Waveforms

5-32 Temperature Coefficient.
Definition: The change in output voltage per degree Centigrade change in the ambient temperature under conditions of constant input ac line voltage, output voltage setting, and load resistance.

5-33 The temperature coefficient of a power supply is measured by placing the power supply in an oven and varying it over any temperature span within its rating. (Most HP power supplies are rated for operation from 0°C to 55°C.) The power supply must be allowed to thermally stabilize for a sufficient period of time at each measurement temperature.

5-34 The temperature coefficient given in the specifications is the maximum temperature-dependent output voltage change which will result over any one degree Centigrade interval. The differential voltmeter or digital voltmeter used to measure the output voltage change of the supply should be placed outside the oven and should have a long term stability adequate to insure that its drift will not affect the overall measurement accuracy.

5-35 To check the temperature coefficient, proceed as follows:

a. Connect load resistance and differential voltmeter as illustrated in Figure 5-2.

b. Turn CURRENT controls fully clockwise.

c. Adjust front panel VOLTAGE controls until front panel voltmeter indicates maximum rated output voltage.

d. Place power supply in temperature-controlled oven (differential voltmeter remains outside oven). Set temperature to 30°C and allow 30 minutes warm-up.

e. Record differential voltmeter reading.

f. Raise temperature to 40°C and allow 30 minutes warm-up.

g. Observe differential voltmeter reading. Difference in voltage reading between Step (e) and (g) should be less than the following:

6227B	5.2mV
6228B	10.2mV

5-36 Output Stability.
Definition: The change in output voltage for the first eight hours following a 30-minute warm-up period. During the interval of measurement all parameters, such as load resistance, ambient temperature, and input line voltage are held constant.

5-37 This measurement is made by monitoring the output of the power supply on a differential voltmeter or digital voltmeter over the stated measurement interval; a strip chart recorder can be used to provide a permanent record. A thermometer should be placed near the supply to verify that the ambient temperature remains constant during the period of measurement. The supply should be put in a location immune from stray air currents (open doors or windows, air conditioning vents); if possible, the supply should be placed in an oven which is held at a constant temperature. Care must be taken that the measuring instrument has a stability over the eight hour interval which is at least an order of magnitude better than the stability specification of the power supply being measured. The supply will drift considerably less over the eight hour measurement interval than during the half-hour warm-up.

5-38 To check the output stability, proceed as follows:

a. Connect load resistance and differential voltmeter as illustrated in Figure 5-2.

b. Turn CURRENT controls fully clockwise.

c. Adjust front panel VOLTAGE controls until differential voltmeter indicates maximum rated output voltage.

d. Allow 30 minutes warm-up, then record differential voltmeter reading.

e. After 8 hours, differential voltmeter should change from reading recorded in Step (d) by less than the following:

6227B	52mV
6228B	102mV

5-39 Output Impedance.
Definition: At any given frequency of load change, E_{OUT}/I_{OUT}. Strictly speaking the definition applies only for a sinusoidal load disturbance, unless, of course, the measurement is made at zero frequency (dc). The

output impedance of an ideal constant voltage power supply would be zero at all frequencies, while the output impedance of an ideal constant current power supply would be infinite at all frequencies.

The output impedance of a power supply is normally not measured, since the measurement of transient recovery time reveals both the static and dynamic output characteristics with just one measurement. The output impedance of a power supply is commonly measured only in those cases where the exact value at a particular frequency is of engineering importance.

5-40 The test setup to be used is shown in Figure 5-7. It is important that the measuring instruments shown in the figure (oscilloscope and microvoltmeter) be connected directly across the power supply output terminals rather than at other points in the test setup. In addition, each instrument should be connected to the power supply with its own pair of leads in order to minimize mutual coupling effects. Monitoring resistor R_M (1 ohm, $\frac{1}{2}$ watt) must be a non-inductive resistor. The value shown for coupling capacitor C_C is the minimum required value; larger values of capacitance can be used without difficulty.

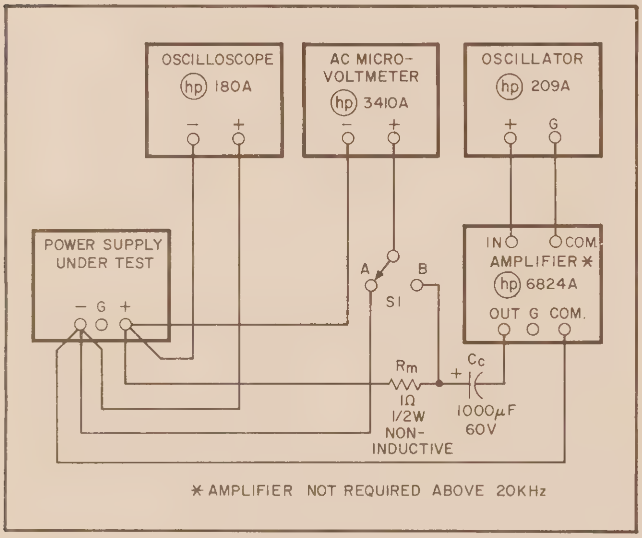


Figure 5-7. Output Impedance Test Setup

5-41 To check the output impedance of the power supply, proceed as follows:

a. Connect test setup shown in Figure 5-7.

b. Turn CURRENT controls fully clockwise.

c. Turn on supply and adjust VOLTAGE controls for maximum rated output voltage.

d. Move switch S1 connected to ac microvoltmeter to position A (measure ac voltage impressed across power supply output terminals).

e. Set oscillator frequency for 5Hz.

f. Adjust amplitude controls of oscillator and amplifier for largest possible undistorted waveform on oscilloscope. Record reading on microvoltmeter.

g. Move switch S1 to position B (measure ac voltage drop across 1 ohm resistor, and therefore ac current delivered to power supply under test).

h. Without changing amplitude controls on oscillator or amplifier, read and record voltage indicated on ac microvoltmeter.

i. Output impedance (at 5Hz) is found by dividing the voltage reading from Step (f) by the voltage reading from Step (h); the value should not exceed 0.002 (ohms) for the 6227B and 0.006 (ohms) for the 6228B.

j. Repeat Steps (d) through (i) for any other frequencies of interest up to 250kHz. (Note: Amplifier is not required at frequencies above 20kHz.) For any given frequency, the output impedance should be less than that indicated by the value of the curve in Figure 5-8. For example, at 1kHz the output impedance should be less than approximately 11 milliohms for the 6227B and 40 milliohms for the 6228B.

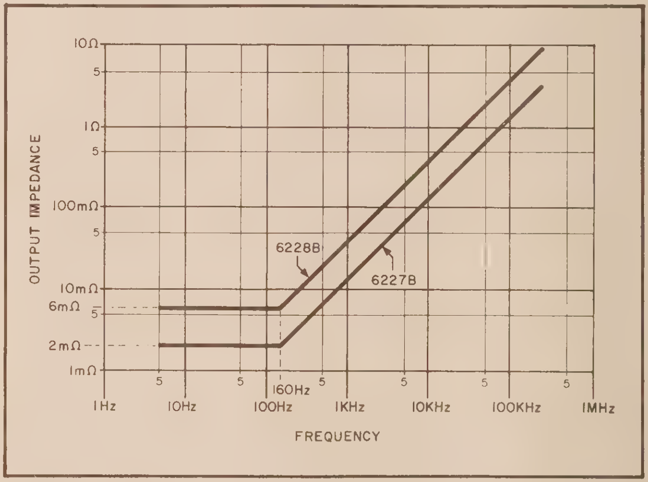


Figure 5-8. Output Impedance versus Frequency

5-42 Tracking Error. The tracking error is defined as the difference in percent between the output voltage of the master and slave supplies when the instrument is operated in the tracking mode. The error is measured once for the complete instrument, as opposed to the previous tests in which the test procedure was repeated for both supplies contained in the instrument. The test setup to be used is shown in Figure 5-9. Only the front output terminals should be used for this test; the rear terminals cannot be used when the instrument is operated in the tracking mode. In addition, note that the minus output terminal of the master (left) supply must be used as the terminal common to both

supplies; the positive terminal of the slave (right) supply should not be used.

5-43 To check the tracking error, proceed as follows:

a. Connect test setup shown in Figure 5-9.

b. Set front panel mode switch to TRACKING, and connect jumper between minus output terminal of left supply and positive output terminal of right supply as shown on front panel and in Figure 5-9.

c. Turn CURRENT controls fully clockwise and set switch S1 to position A (measure master supply output voltage).

d. Turn on supply and adjust master VOLTAGE controls until differential voltmeter reads exactly maximum rated output voltage.

e. Move switch S1 to position B (measure slave output voltage). Differential voltmeter reading should be within following tolerances:

6227B	25V ± 52mV
6228B	50V ± 102mV

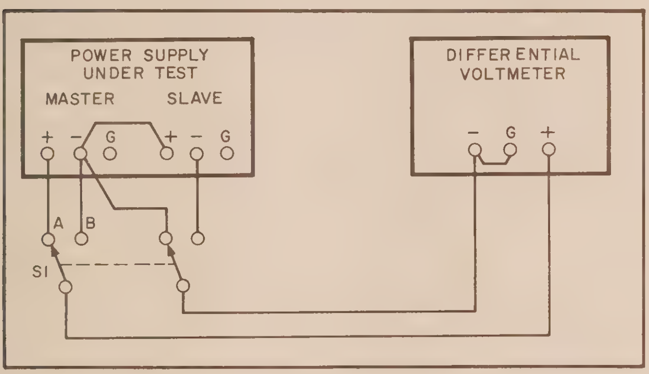


Figure 5-9. Tracking Error Test Setup

5-44 CONSTANT CURRENT TESTS

5-45 The instruments, methods, and precautions for the proper measurement of constant current power supply characteristics are for the most part identical to those already described for the measurement of constant voltage power supplies. There are, however, two main differences: First, the power supply performance will be checked between short circuit and full load rather than open circuit and full load. Second, a current monitoring resistor is inserted between the output of the power supply and the load.

5-46 For all output current measurements the current sampling resistor must be treated as a four terminal device. In the manner of a meter shunt, the load current is fed to the extremes of the wire leading to the resistor while the sampling terminals are located as close as possible to the resistance portion itself (see Figure 5-10). Generally, any current sampling resistor should be of the low noise, low temperature coefficient (less than 20ppm/°C) type and should be used at no more than 10% of its rated power so that its temperature rise will be minimized. If difficulty is experienced in obtaining a resistor suitable for current sampling, a duplicate of the sampling resistor used in this unit (R10 and R11 in the 6227B; R10 in the 6228B) may be obtained from the factory.

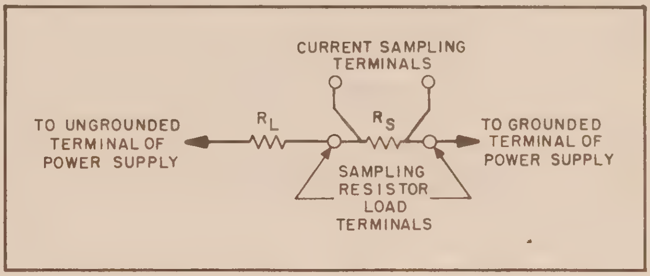


Figure 5-10. Current Sampling Resistor Connections

5-47 Rated Output and Meter Accuracy.

a. Connect test setup shown in Figure 5-11.

b. Turn VOLTAGE controls fully clockwise.

c. Turn on supply and adjust CURRENT controls until front panel ammeter indicates maximum rated output current.

d. Differential voltmeter should read 1.0 ± 0.024Vdc.

5-48 Load Regulation.

Definition: The change ΔI_{OUT} in the static value of the dc output current resulting from a change in load resistance from short circuit to a value which yields maximum rated output voltage.

5-49 To check the constant current load regulation, proceed as follows:

a. Connect test setup shown in Figure 5-11.

b. Turn VOLTAGE controls fully clockwise.

c. Adjust CURRENT controls until front panel meter reads exactly maximum rated output voltage.

d. Read and record voltage indicated on differential voltmeter.

e. Short circuit load resistor (R_L).

f. Reading on differential voltmeter should not vary from reading recorded in Step (d) by more than the following:

6227B	225µV
6228B	350µV

5-50 Line Regulation.

Definition: The change ΔI_{OUT} in the static value of dc output current resulting from a change in ac input voltage over the specified range from low

line (usually 103.5 volts) to high line (usually 126.5 volts), or from high line to low line.

5-51 To check the line regulation, proceed as follows:

a. Utilize test setup shown in Figure 5-11.

b. Connect variable auto transformer between input power source and power supply power input.

c. Adjust auto transformer for 103.5Vac input.

d. Turn VOLTAGE controls fully clockwise.

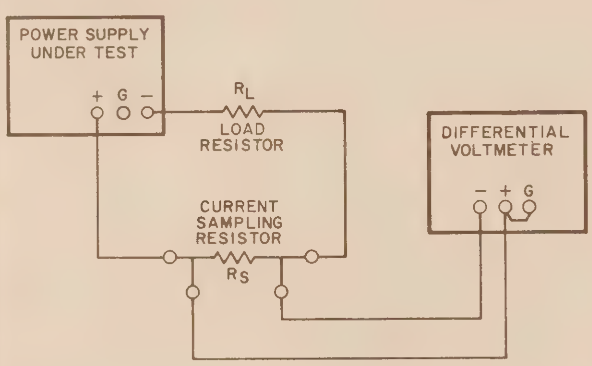
e. Adjust CURRENT controls until front panel ammeter reads exactly maximum rated output current.

f. Read and record voltage indicated on differential voltmeter.

g. Adjust variable auto transformer for 126.5Vac input.

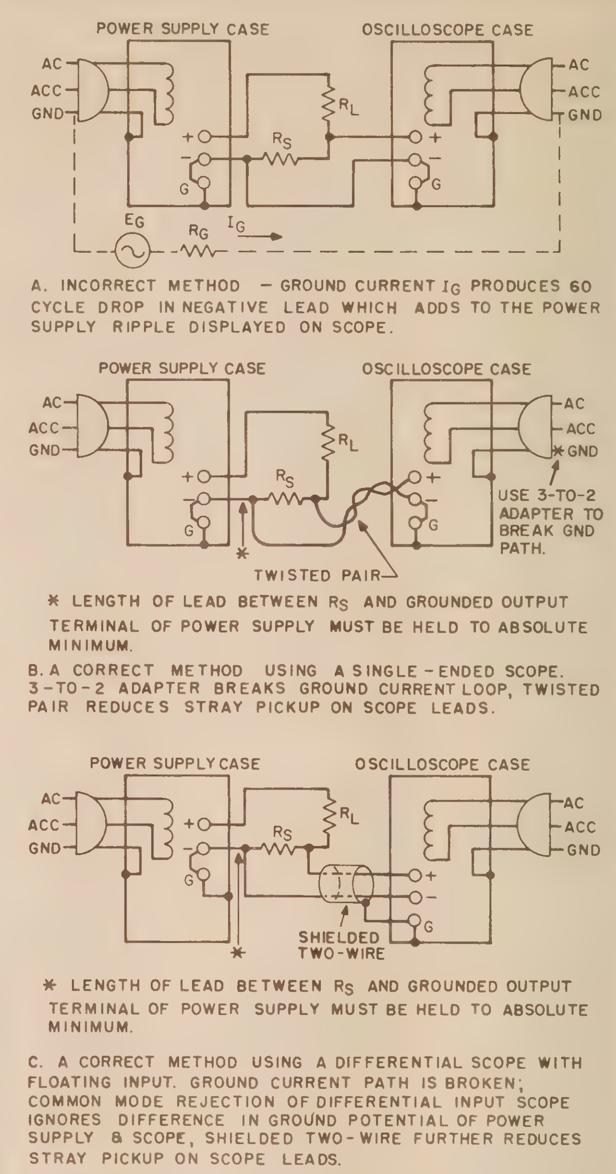
h. Reading on differential voltmeter should not vary from reading recorded in Step (f) by more than the following:

6227B	50μV
6228B	100μV



MODEL NO.	R_L	R_S
6227B	12Ω, 50W, ±5%	0.5Ω, 16W, ±0.5%, ±10ppm
6228B	49Ω, 50W, ±5%	1Ω, 8W, ±0.5%, ±10ppm

Figure 5-11. Constant Current Load Regulation Test Setup



MODEL NO.	R_L	R_S
6227B	12Ω, 50W, ±5%	0.5Ω, 16W, ±0.5%, ±10ppm
6228B	49Ω, 50W, ±5%	1Ω, 8W, ±0.5%, ±10ppm

Figure 5-12. Constant Current Ripple Test Setup

5-52 Ripple and Noise.

Definition: The residual ac current which is superimposed on the dc output current of a regulated power supply. Ripple and noise may be specified and measured in terms of its RMS or (preferably) peak-to-peak value.

5-53 Most of the instructions pertaining to the ground loop and pickup problems associated with constant voltage ripple and noise measurements also apply to the measurement of constant current ripple and noise. Figures 5-12 and 5-13 illustrate the most important precautions to be observed when measuring the ripple and noise of a constant current supply. The presence of a 120Hz waveform on the oscilloscope is normally indicative of a correct measurement method. A waveshape having 60Hz as its fundamental component is typically associated with an incorrect measurement setup.

5-54 Ripple Measurement. To check the ripple

output, proceed as follows:

a. Connect oscilloscope or RMS voltmeter as shown in Figures 5-12B or 5-12C.

b. Turn VOLTAGE controls fully clockwise.

c. Adjust CURRENT controls until front panel ammeter reads exactly maximum rated output current.

d. The observed ripple should be less than:

6227B 125μV
6228B 250μV

5-55 Noise Spike Measurement. To check the noise spike output, proceed as follows:

a. Connect test setup shown in Figure 5-13.

b. Turn VOLTAGE controls fully clockwise.

c. Adjust CURRENT controls until front panel ammeter indicates exactly rated output current.

d. The observed noise spikes should be less than 1.0mV p-p.

5-56 ADJUSTMENT AND CALIBRATION

5-57 Adjustment and calibration may be required after performance testing, troubleshooting, or repair and replacement. Perform only those adjustments that affect the operation of the faulty circuit and no others. Except where otherwise indicated, all of the following adjustments must be performed twice—once for each of the two independent power supplies contained in the instrument.

5-58 METER ZERO

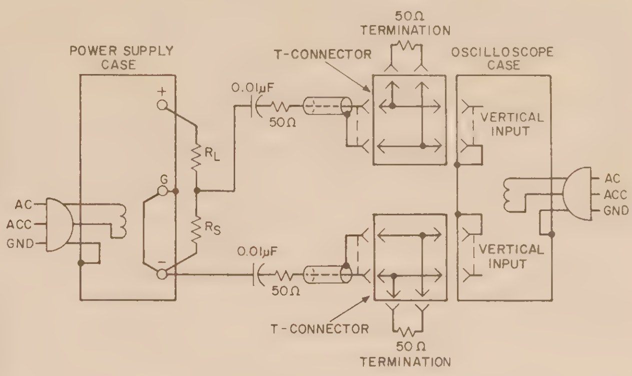
5-59 The meter pointer must rest on the zero calibration mark on the meter scale when the instrument is at normal operating temperature, resting in its normal operating position, and turned off. To zero set the meter proceed as follows:

a. Turn on instrument and allow it to come up to normal operating temperature (about 30 minutes).

b. Turn instrument off. Wait one minute for power supply capacitors to discharge completely.

c. Insert sharp pointed object (pen point or awl) into small indentation near top of round black plastic disc located directly below meter face.

d. Rotate plastic disc clockwise until meter reads zero, then rotate counterclockwise slightly



MODEL NO.	R_L	R_S
6227B	12Ω, 50W, ± 5%	0.5Ω, 16W, ±0.5%, ±10ppm
6228B	49Ω, 50W, ± 5%	1Ω, 8W, ±0.5%, ±10ppm

Figure 5-13. Constant Current Noise Spike Test Setup

Table 5-2. Calibration and Adjustment Summary

ADJUSTMENT OR CALIBRATION	PRINCIPLES OF OPERATION PARAGRAPH	ADJUSTMENT PARAGRAPH	ADJUST
Ammeter/Voltmeter Zero		5-58	Pointer
Ammeter Calibration		5-62	R86
Voltmeter Calibration		5-63	R80
Constant Voltage Zero Output Voltage		5-65	R24
Constant Voltage Programming Accuracy		5-67	R16
Constant Current Zero Output Current		5-69	R5 or R7
Constant Current Programming Accuracy		5-71	R2

in order to free adjustment screw from meter suspension. Pointer should not move during latter part of adjustment.

5-60 METER CALIBRATION

5-61 Because of interaction between the ammeter and voltmeter calibration potentiometers, the ammeter must be calibrated before the voltmeter.

5-62 Ammeter Calibration. To calibrate the ammeter, proceed as follows:

a. Connect test setup shown in Figure 5-11.

b. Turn VOLTAGE controls fully clockwise and set meter switch to AMPS.

c. Turn on supply and adjust CURRENT controls until differential voltmeter reads 1.0 volts.

d. Adjust potentiometer R86 until front panel meter indicates exactly maximum rated output current.

5-63 Voltmeter Calibration. To calibrate the voltmeter, proceed as follows:

a. Connect test setup shown in Figure 5-2.

b. Turn CURRENT controls fully clockwise and set meter switch to VOLTS.

c. Turn on supply and adjust VOLTAGE controls until differential voltmeter reads exactly maximum rated output voltage.

d. Adjust potentiometer R80 until front panel meter also reads exactly maximum rated output voltage.

5-64 CONSTANT VOLTAGE PROGRAMMING CURRENT

5-65 Zero Output Voltage. In order for the instrument to meet the tracking error specification, the slave supply's zero output voltage adjustment must be made with the instrument in the TRACKING mode. Because of this requirement, when operated in the INDEPENDENT mode and programmed for zero output with the front panel pot, the slave's output voltage may be a maximum of 60mV above zero. If the slave supply is adjusted in the INDEPENDENT mode to remove this positive voltage, the instrument will not meet the tracking specification. The The master supply's zero output voltage adjustment may be made with the instrument operating in either the TRACKING or the INDEPENDENT mode, though adjustment in the TRACKING mode is somewhat more convenient due to the restriction that the slave be adjusted in the TRACKING mode. Note that since the master supply is the reference against which the slave supply tracks, the master supply's zero output voltage adjustment must be made before the slave supply is adjusted.

5-66 To calibrate the zero voltage programming accuracy, proceed as follows:

a. Connect test setup shown in Figure 5-9, and set switch S1 to position "A".

b. Set front panel mode switch to TRACKING, and connect jumper between minus output terminal of left supply and positive output terminal of right supply as shown on front panel and in Figure 5-9.

c. If instrument is to be locally programmed, turn master VOLTAGE controls fully counterclockwise. If instrument is to be remote programmed, connect remote programming setup (Figures 3-3, 3-4, and 3-5) to master supply, and adjust remote resistance or voltage to zero (minimum).

Rotate both sets of CURRENT controls fully clockwise and turn on supply.

e. Adjust potentiometer R24 in master supply until differential voltmeter reads exactly zero.

f. Move switch S1 to position "B".

g. Adjust potentiometer R24 in slave supply until differential voltmeter reads exactly zero.

5-67 CV Programming Accuracy. The voltage programming accuracy is determined by the voltage programming current flowing through both the pull-out resistors (R15, R16) and the voltage controls (R27A, R27B); this current determines the programming coefficient. The following procedure adjusts the voltage programming current to obtain a coefficient of exactly 200 ohms per volt:

a. Connect a 0.1%, 1 watt resistor of value shown below between terminals -S and A2 on rear barrier strip.

6227B	5KΩ
6228B	10KΩ

b. Remove strap between terminals A2 and A3 on rear barrier strip.

c. Connect decade resistance box in place of resistor R16.

d. Connect differential voltmeter across rear output terminals of supply.

e. Turn CURRENT controls fully clockwise and turn on supply.

f. Adjust decade resistance box until differential voltmeter indicates exactly maximum rated output voltage.

g. Replace decade resistance box with resistor of appropriate value in R16 position.

5-68 CONSTANT CURRENT PROGRAMMING CURRENT

5-69 Zero Current Output. Since constant current operation is not possible when the instrument is operated in the TRACKING mode, the zero current output adjustment for both supplies must be made separately with the instrument operating in the INDEPENDENT mode. The adjustment procedure varies the bias voltage on the base of one side of the constant current comparator differential amplifier.

5-70 To calibrate the zero current programming accurcy, proceed as follows:

a. Connect test setup shown in Figure 5-11.

b. If supply is to be locally programmed, turn CURRENT controls fully counterclockwise. If supply is to be remote programmed, connect remote programming setup (Figure 3-6, 3-7, or 3-8) and adjust remote resistance or voltage to zero (minimum).

c. Rotate CURRENT controls fully clockwise and turn on supply.

d. Observe reading on differential voltmeter. If it is more positive than 0 volts, shunt resistor R5 with decade resistance box.

e. Adjust decade resistance until differential voltmeter reads zero, then shunt R5 with resistance value equal to that of decade resistance.

f. If reading of Step (d) is more negative than 0 volts, shunt resistor R7 with decade resistance box.

g. Adjust decade resistance until differential voltmeter reads zero, then shunt resistor R7 with resistance value equal to that of decade box.

5-71 <u>CC Programming Accuracy</u>. To calibrate the constant current programming current, proceed as follows:

a. Connect test setup shown in Figure 5-11.

b. Remove strap between terminals A6 and A7 on rear barrier strips.

c. Connect a 1KΩ, 0.1%, 1/8 watt resistor between terminals A4 and A6.

d. Connect decade resistance box in place of resistor R2.

e. Rotate VOLTAGE controls fully clockwise and turn on supply.

f. Adjust decade resistance until differential voltmeter reads 1.0V.

g. Replace decade resistance with appropriate value resistor in R2 position.

5-72 CROWBAR DISABLEMENT

5-73 To disable the overvoltage protection crowbars completely, disconnect the cathodes of SCR's CR4(A) and CR4(B). The SCR's are mounted on the chassis (see Figures 7-2 and 7-4); their connecting wires are easily accessed by removing the bottom cover of the instrument.

SECTION VI
REPLACEABLE PARTS

6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts.

6-3 Table 6-4 lists parts in alpha-numerical order of the reference designators and provides the following information:

a. Reference Designators. For abbreviations, refer to Table 6-1.

b. Description. Refer to Table 6-2 for abbreviations.

c. Total Quantity (TQ) used in the instrument; given only first time the part number is listed.

d. Manufacturer's part number.

e. Manufacturer's code number. Refer to Table 6-3 for manufacturer's name and address.

f. ⓗ Part Number.

g. Recommended spare parts quantity (RS) for complete maintenance of one instrument during one year of isolated service.

h. Parts not identified by a reference designator are listed at the end of Table 6-4 under Miscellaneous.

6-4 ORDERING INFORMATION

6-5 To order a replacement part, address order or inquiry to your local Hewlett-Packard sales office (see lists at rear of this manual for addresses).

6-6 Specify the following information for each part:

a. Model and complete serial number of instrument.

b. Hewlett-Packard part number.

c. Circuit reference designator.

d. Description.

6-7 To order a part not listed in Table 6-4, give a complete description of the part and include its function and location.

Table 6-1. Reference Designators

A = assembly	CR = diode
B = motor	DS = device, signaling (lamp)
C = capacitor	

Table 6-1. Reference Designators (Continued)

E = misc. electronic part	RT = thermistor
F = fuse	S = switch
J = jack	T = transformer
K = relay	V = vacuum tube, neon bulb, photocell, etc.
L = inductor	X = socket
M = meter	XF = fuseholder
P = plug	XDS = lampholder
Q = transistor	Z = network
R = resistor	

Table 6-2. Description Abbreviations

a = amperes	obd = order by description
c = carbon	p = peak
cer = ceramic	pc = printed circuit board
coef = coefficient	pf = picofarads = 10^{-12} farads
com = common	pp = peak-to-peak
comp = composition	ppm = parts per million
conn = connection	pos = position(s)
crt = cathode-ray tube	poly = polystyrene
dep = deposited	pot = potentiometer
elect = electrolytic	prv = peak reverse voltage
encap = encapsulated	rect = rectifier
f = farads	rot = rotary
fxd = fixed	rms = root-mean-square
GE = germanium	s-b = slow-blow
grd = ground(ed)	sect = section(s)
h = henries	Si = silicon
Hg = mercury	sil = silver
impg = impregnated	sl = slide
ins = insulation(ed)	td = time delay
K = kilo = 1000	TiO_2 = titanium dioxide
lin = linear taper	tog = toggle
log = logarithmic taper	tol = tolerance
mA = milli = 10^{-3}	trim = trimmer
M = megohms	twt = traveling wave tube
ma = milliamperes	var = variable
μ = micro = 10^{-6}	w/ = with
mfr = manufacturer	W = watts
mtg = mounting	w/o = without
my = mylar	cmo = cabinet mount only
NC = normally closed	
Ne = neon	
NO = normally open	

Table 6-3. Code List of Manufacturers

CODE NO.	MANUFACTURER	ADDRESS
00629	EBY Sales Co.	New York, N.Y.
00656	Aerovox Corp.	New Bedford, Mass.
00853	Sangamo Electric Company, Ordill Division (Capacitors)	Marion, Ill.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	Lawndale, Calif.
01295	Texas Instruments, Inc. Semiconductor-Components Division	Dallas, Texas
01686	RCL Electronics, Inc.	Manchester, N.H.
01930	Amerock Corp.	Rockford, Ill.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02606	Fenwal Laboratories	Morton Grove, Ill.
02660	Amphenol-Borg Electronics Corp.	Broadview, Ill.
02735	Radio Corp. of America, Commercial Receiving Tube and Semiconductor Div.	Somerville, N.J.
03508	G. E. Semiconductor Products Dept.	Syracuse, N.Y.
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electronic Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co.	Cedar Knolls, N.J.
04009	Arrow, Hart and Hegeman Electric Co.	Hartford, Conn.
04072	ADC Electronics, Inc.	Harbor City, Calif.
04213	Caddell-Burns Mfg. Co. Inc.	Mineola, N.Y.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.
04713	Motorola, Inc., Semiconductor Products Division	Phoenix, Arizona
05277	Westinghouse Electric Corp. Semi-Conductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	Grand Junction, Colo.
05820	Wakefield Engr. Inc.	Wakefield, Mass.
06004	The Bassick Co.	Bridgeport, Conn.
06486	IRC, Inc. Semiconductor Div.	Lynn, Mass.
06540	Amathom Electronic Hardware Co., Inc.	New Rochelle, N.Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06666	General Devices Co., Inc.	Indianapolis, Ind.
06751	Nuclear Corp. of America, Inc. U.S. Semcor Div.	Phoenix, Arizona
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.
07263	Fairchild Semiconductor Div. of Fairchild Camera and Instrument Corp.	Mountain View, Calif.
07387	Birtcher Corp., The	Los Angeles, Calif.
07397	Sylvania Electric Products Inc. Mountain View Operations of Sylvania Electronic Systems	Mountain View, Calif.
07716	I. R. C. Inc.	Burlington, Iowa
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Raytheon Mfg. Co., Semiconductor Div.	Mountain View, Calif.
08484	Breeze Corporations, Inc.	Union, N.J.
08530	Reliance Mica Corp.	Brooklyn, N.Y.
08717	Sloan Company	Sun Valley, Calif.
08730	Vemaline Products Co.	Franklin Lakes, N.J.
08863	Nylomatic Corp.	Morrisville, Pa.
09021	Airco Speer Electronic Components	Bradford, Pa.
09182	Hewlett-Packard Co., New Jersey Div.	Berkeley Heights, N.J.
09353	C & K Components	Newton, Mass.
09922	Burndy Corp.	Norwalk, Conn.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11502	IRC Inc.	Boone, N.C.
11711	General Instrument Corp., Semiconductor Prod. Group, Rectifier Div.	Newark, N.J.
12136	Philadelphia Handle Co., Inc.	Camden, N.J.
12615	U.S. Terminals, Inc.	Cincinnati, Ohio
12617	Hamlin Inc.	Lake Mills, Wisconsin
12697	Clarostat Mfg. Co.	Dover, N.H.
14493	Hewlett-Packard Co., Loveland Division	Loveland, Colo.
14655	Cornell-Dubilier Elec. Corp.	Newark, N.J.
14936	General Instrument Corp., Semiconductor Prod. Group, Semiconductor Div.	Hicksville, N.Y.
15909	Daven Div. of Thos. Edison Industries, Mc Graw Edison Co.	Livingston, N.J.
16299	Corning Glass Works, Electronic Components Div.	Raleigh, N.C.
16758	Delco Radio Div. of General Motors Corp.	Kokomo, Ind.
17545	Atlantic Semiconductors, Inc.	Asbury Park, N.J.
17803	Fairchild	Mountainview, Calif.
19315	The Bendix Corp., Eclipse Pioneer Div.	Teterboro, N.J.
19701	Electra Mfg. Co.	Independence, Kan.

CODE NO.	MANUFACTURER	ADDRESS
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
22229	Union Carbide Corp., Linde Div., Kemet Dept.	Mountain View, Calif.
22767	ITT Semiconductors, A Division of International Telephone & Telegraph Corp.	Palo Alto, Calif.
24446	General Electric Co.	Schenectady, N.Y.
24455	General Electric Co., Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26982	Dynacool Mfg. Co. Inc	Saugerties, N.Y.
27014	National Semiconductor Corp.	Santa Clara, Calif.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
28520	Heyman Mfg. Co.	Kenilworth, N.J.
33173	G. E., Tube Dept.	Owensboro, Ky.
35434	Lectrohm, Inc.	Chicago, Ill.
37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.
42190	Muter Co.	Chicago, Ill.
43334	New Departure-Hyatt Bearings Div., General Motors Corp.	Sandusky, Ohio
44655	Ohmite Manufacturing Co.	Skokie, Ill.
46384	Penn Engr.	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass.
49956	Raytheon Mfg. Co., Microwave and Power Tube Div.	Waltham, Mass.
55026	Simpson Electric Co.	Chicago, Ill.
56289	Sprague Electric Co.	North Adams, Mass.
58474	Superior Electric Co.	Bristol, Conn.
61637	Union Carbide Corp.	New York, N.Y.
63743	Ward-Leonard Electric Co.	Mt. Vernon, N.Y.
70563	Amperite Co., Inc.	Union City, N.J.
70901	Beemer Engrg. Co.	Fort Washington, Pa.
70903	Belden Mfg. Co.	Chicago, Ill.
71218	Bud Radio, Inc.	Willoughby, Ohio
71279	Cambridge Thermionic Corp.	Cambridge, Mass.
71400	Bussmann Mfg. Div. of Mc Graw-Edison Co.	St. Louis, Mo.
71450	CTS Corporation	Elkhart, Ind.
71468	I. T. T. Cannon Electric Inc.	Los Angeles, Calif.
71590	Centralab Div. of Globe Union, Inc.	Milwaukee, Wis.
71700	The Cornish Wire Co.	New York, N.Y.
71707	Coto-Coil	Providence, R.I.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71785	Cinch Mfg. Co.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro-Motive Mfg. Co. Inc., The	Willimantic, Conn.
72619	Dialight Corp.	Brooklyn, N.Y.
72699	General Instrument Corp., Capacitor Div.	Newark, N.J.
72765	Drake Mfg. Co.	Chicago, Ill.
72962	Elastic Stop Nut Corp. of America	Union, N.J.
72982	Erie Technological Products, Inc.	Erie, Pa.
73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
73168	Fenwal, Inc.	Ashland, Mass.
73293	Hughes Components Division of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73734	Federal Screw Porducts, Inc.	Chicago, Ill.
73978	Hardwick Hindle Co., Memcor Components Div.	Huntington, Ind.
74193	Heinemann Electric Co.	Trenton, N.J.
74545	Harvey Hubbel, Inc.	Bridgeport, Conn.
74868	FXR Div. of Amphenol-Borg Electronics Corp.	Danbury, Conn.
74970	E. F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75183	Howard B. Jones Div., of Cinch Mfg. Corp. (Use 71785)	New York, N.Y.
75382	Kulka Electric Corp.	Mt. Vernon, N.Y.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76381	Minnesota, Mining & Mfg. Co.	St. Paul, Minn.
76493	J. W. Miller Co.	Los Angeles, Calif.
76530	Cinch	City of Industry, Calif.
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	Bendix Corp., Bendix-Pacific Div.	No. Hollywood, Calif.
77147	Patton Mac Guyer Co.	Providence, R.I.
77221	Phaostron Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine and Foundry, Potter and Brumfield Div.	Princeton, Ind.
77630	TRW Electronics, Components Div.	Camden, N.J.
77764	Resistance Products Co.	Harrisburg, Pa.
78189	Shakeproof Div. of Illinois Tool Works	Elgin, Ill.
78452	Everlock Chicago, Inc.	Chicago, Ill.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78526	Stanwyck Winding Co., Inc.	Newburgh, N.Y.
78553	Tinnerman Products, Inc.	Cleveland, Ohio

CODE NO.	MANUFACTURER	ADDRESS
78584	Stewart Stamping Corp.	Yonkers, N.Y.
79136	Waldes Kohinoor, Inc.	L.I.C., N.Y.
79307	Whitehead Metal Products Co., Inc.	New York, N.Y.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
80031	Mepco Div. of Sessions Clock Co.	Morristown, N.J.
80294	Bourns, Inc.	Riverside, Calif.
81042	Howard Industries, Inc.	Racine, Wis.
81483	International Rectifier Corp.	El Segundo, Calif.
81751	Columbus Electronics Corp.	Yonkers, N.Y.
82099	Goodyear Sundries & Mechanical Co., Inc.	New York, N.Y.
82142	Airco Speer Electronic Components	Du Bois, Pa.
82219	Sylvania Electric Products, Inc., Electronic Tube Division	Emporium, Pa.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals and Controls, Inc., Spencer Products	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Mfg. Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83186	Victory Engineering Corp.	Springfield, N.J.
83298	Bendix Corp., Red Bank Div.	Eatontown, N.J.
83330	Herman H. Smith, Inc.	Brooklyn, N.Y.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.
83508	Grant Pulley and Hardware Co.	West Nyack, N.Y.
83594	Burroughs Corp., Electronic Components Div.	Plainfield, N.J.
83835	U.S. Radium Corp.	Morristown, N.J.
83877	Yardeny Laboratories, Inc.	New York, N.Y.
84171	Arco Electronics, Inc.	Great Neck, N.Y.
84411	TRW Capacitor Div.	Ogallala, Neb.
86684	Radio Corp. of America, Electronic Components & Devices Div.	Harrison, N.J.
86838	Rummel Fibre Co.	Newark, N.J.
87034	Marco Industries Co.	Anaheim, Calif.
87216	Philco Corp. (Lansdale Div.)	Lansdale, Pa.
87585	Stockwell Rubber Co., Inc.	Philadelphia, Pa.
87929	B. M. Tower Co., Inc.	Bridgeport, Conn.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
89473	General Electric Distributing Corp.	Schenectady, N.Y.
91345	Miller Dial and Nameplate Co.	El Monte, Calif.
91637	Dale Electronics, Inc.	Columbus, Neb.
91662	Elco Corp.	Willow Grove, Pa.
91929	Honeywell, Inc., Micro Switch Div.	Freeport, Ill.
93332	Sylvania Electric Prod., Inc., Semiconductor Prod. Div.	Woburn, Mass.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
94144	Raytheon Co., Components Div., Industrial Components Operation	Quincy, Mass.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94222	South Chester Corp.	Chester, Pa.
94310	Tru-Ohm Products, Memcor Components Div.	Huntington, Ind.
95263	Leecraft Mfg. Co., Inc.	Long Island City, N.Y.
95354	Methode Mfg. Co.	Chicago, Ill.
95712	Bendix Corp, Microwave Div.	Franklin, Ind.
96791	Amphenol Controls Div. of Amphenol-Borg Electronics Corp.	Janesville, Wis.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98978	International Electronic Research Corp.	Burbank, Calif.
99934	Renbrandt, Inc.	Boston, Mass.

THE FOLLOWING H-P VENDORS HAVE NO NUMBERS ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

CODE NO.	MANUFACTURER	ADDRESS
0000	Cooltron	Oakland, Calif.
00000	Plastic Ware Co.	Brooklyn, N.Y.

Table 6-4. Replaceable Parts

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
	A1 MOTHER BOARD - ELECTRICAL					
A1	Printed Circuit Board, Mother	1		09182	06228-60020	
C9A, 9B	fxd, elect 325μF 35Vdc	2		09182	0180-0332	1
C10A, 10B	fxd, elect 80μF 65Vdc	2	72D1005	56289	0180-2258	1
C11A-14A, 11B-14B	fxd, ceramic .05μF 500V	8	33C17A	56289	0150-0052	2
CR15A-18A, 15B-18B	Rect. Si. 3A 200prv	8	MR1032B	04713	1901-0416	6
CR19A, 19B, 20A, 20B, 21A, 21B, 22A, 22B	Rect. Si. 200mA 180V	8	1N5059	03508	1901-0327	6
R75A, 75B	fxd, ww 25Ω ±5% 5W	2	Type 5XM	63743	0811-1856	1
R76A, 76B	fxd, ww 2K ±5% 5W	2	Type 5XM	63743	0812-0100	1
R91, 92	fxd, ww 4.5K ±.1% ±10ppm $2\frac{1}{2}$W	2	Type T2C	01686	0811-1993	1
T1	Transformer, Power	1		09182	06228-80091	
	A2 MASTER BOARD - ELECTRICAL					
A2	Printed Circuit Board, Master	1		09182	06228-60021	
C1	fxd, elect 750μF 75Vdc	1		09182	0180-1891	1
C2	fxd, elect 5μF 65Vdc	2		09182	0180-1836	1
C3	fxd, mylar .01μF 200V	1	192P10392	56289	0160-0161	1
C4	fxd, mylar .001μF 200Vdc	1	192P22292	56289	0160-0153	1
C5	fxd, mylar .1μF 200Vdc	1	192P10492	56289	0160-0168	1
C6, 7	fxd, elect 1600μF 85Vdc	2		09182	0180-1986	1
C11	fxd, elect 4.7μF 35Vdc	1	150D475X9035B2	56289	0180-0100	1
C13	fxd, elect 5μF 65Vdc			09182	0180-1836	
C15	fxd, mylar .47μF 25V	1	5C11B75	56289	0160-0174	1
CR1	Diode, Si. 250mW 200V	5		09182	1901-0033	5
CR2	Rect. Si. 3A 200prv	3	MR1032B	04713	1901-0416	3
CR3	Diode, Si. 250mA 75V	1		09182	1901-0050	1
CR4	Diode, Si. 400mW 15V	3		09182	1901-0461	3
CR5-7	Diode, Si. 250mW 200V			09182	1901-0033	
CR8, 9	Diode, Si. 400mW 15V			09182	1901-0461	
CR10	Diode, Si. 250mW 200V			09182	1901-0033	
CR11	Diode, Si. 400mW 10V	1		09182	1901-0460	1
CR12	Rect. Si. 1A 200prv	1	1N5059	03508	1901-0327	1
CR13, 14	Rect. Si. 3A 200prv		MR1032B	04713	1901-0416	
F2	Fuse Cartridge, 2A 250V 3AG Normal Blow Pigtail	1		09182	2110-0262	5
Q1, 2, 7-11	NOT ASSIGNED	-	-	-	-	-
Q3	SS PNP Si.	3		09182	1853-0099	3
Q4	SS NPN Si.	5		09182	1854-0071	5
Q5	SS PNP Si.			09182	1853-0099	
Q6, 12-14	SS NPN Si.			09182	1854-0071	
Q15	SS PNP Si.			09182	1853-0099	
R1	fxd, ww 7.5KΩ ±5% 3W	1	Type 242E	56289	0811-1815	1
R2	fxd, comp (Selected) ±5% $\frac{1}{2}$W	2	Type EB (obd)	01121		
R3	fxd, met. film 1KΩ ±1% 1/8W	2	Type CEA T-O	07716	0757-0280	1
R5	fxd, comp 220KΩ ±5% $\frac{1}{2}$W	1	EB-2245	01121	0686-2245	1

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
R6	fxd, met. film 1.5KΩ ±1% 1/8W	2	Type CEA T-O	07716	0757-0427	1
R7	fxd, comp 750KΩ ±5% ½W	1	EB-7545	01121	0686-7545	1
R8	fxd, comp 75Ω ±5% ½W	2	EB-7505	01121	0686-7505	1
R9,11,14, 17,22,23 27-29,39, 43,47,49, 53-67,78, 79,82,83	NOT ASSIGNED	-	-	-	-	-
R10,	fxd, ww 1Ω ±0.5% 8W	1	Type T-7A	01686	0811-2133	1
R12	fxd, comp 3.3Ω ±5% ½W	2	EB-0335	01121	0686-0335	1
R13	fxd, met. film 200KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0472	1
R15	fxd, ww 1.3KΩ ±5% 3W	1	Type 242E	56289	0811-1803	1
R16	fxd, comp (Selected) ±5% ½W		Type EB (obd)	01121		
R18,19	fxd, comp 100Ω ±5% ½W	3	EB-1015	01121	0686-1015	1
R20	fxd, ww 1KΩ ±5% 3W	1	Type 242E	56289	0813-0001	1
R21	fxd, comp 200Ω ±5% ½W	2	EB-2015	01121	0686-2015	1
R24	var. comp 25KΩ ±30% (Zero Volt Adjust)	1		09182	2100-1534	1
R25	fxd, met. film 1.5KΩ ±1% 1/8W		Type CEA T-O	07716	0757-0427	
R26	fxd, met. film 249KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0270	1
R30	fxd, met. film 61.9KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0460	1
R31	fxd, met. film 2KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0283	1
R32	fxd, met. film 3.4KΩ ±1% 1/8W	2	Type CEA T-O	07716	0698-4440	1
R33	fxd, comp 390Ω ±5% ½W		EB-3915	01121	0686-3915	
R34	fxd, comp 10KΩ ±5% ½W	2	EB-1035	01121	0686-1035	1
R35	fxd, met. film 6.2KΩ ±1% 1/8W	1	Type CEA T-O	07716	0698-5087	1
R36	fxd, comp 2KΩ ±5% ½W	1	EB-2025	01121	0686-2025	1
R37	fxd, comp 470Ω ±5% ½W	1	EB-4715	01121	0686-4715	1
R38	fxd, comp 150Ω ±5% ½W	1	EB-1515	01121	0686-1515	1
R40	fxd, met. film 470Ω ±1% ¼W	1	Type CEB T-O	07716	0698-3506	1
R41,42	fxd, met. film 7.5KΩ ±1% 1/8W	2	Type CEA T-O	07716	0757-0440	1
R44	fxd, met. film 600Ω ±1% 1/8W	1	Type CEA T-O	07716	0757-1100	1
R45	fxd, comp 10KΩ ±5% ½W		EB-1035	01121	0686-1035	
R46	fxd, comp 470Ω ±5% ½W		EB-4715	01121	0686-4715	
R48	fxd, met. film 2KΩ ±1% ¼W	1	Type CEB T-O	07716	0757-0739	1
R50	fxd, met. film 5.49KΩ ±1% 1/8W	1	Type CEA T-O	07716	0698-3382	1
R51	fxd, comp 820Ω ±5% ½W	1	EB-8215	01121	0686-8215	1
R52	fxd, met. film 3.4KΩ ±1% 1/8W		Type CEA T-O	07716	0698-4440	
R68,69	fxd, ww 1Ω ±5% 3W 20ppm	4		09182	0811-1732	1
R70	fxd, comp 3.3Ω ±5% ½W		EB-0335	01121	0686-0335	
R71	fxd, comp 91Ω ±5% ½W	1	EB-9105	01121	0686-9105	1
R72	fxd, comp 200Ω ±5% ½W		EB-2015	01121	0686-2015	
R73,74	fxd, ww 1Ω ±5% 3W 20ppm			09182	0811-1732	
R77	fxd, ww 2KΩ ±5% 5W	1	Type 5XM	63743	0812-0100	1
R80	var. ww 5KΩ ±20% (Voltmeter Adjust)	1	Type 110-F4	11236	2100-1824	1
R81	fxd, met. film 57.6KΩ ±1% ¼W	1	Type CEB T-O	07716	0757-0114	1
R84	Thermistor 64Ω	1		09182	0837-0023	1
R85	fxd, met. film 42.2Ω ±1% 1/8W	1	Type CEA T-O	07716	0757-0316	1
R86	var. ww 250Ω ±20% (Ammeter Adjust)	1	Type 110-F4	11236	2100-0439	1
R87	fxd, met. film 1KΩ ±1% 1/8W		Type CEA T-O	07716	0757-0280	1
R88	fxd, met. film 196Ω ±1% 1/8W	1	Type CEA T-O	07716	0698-3440	1
VR1,2	Diode, zener 6.2V 250mW	2		09182	1902-1221	2
VR3,4	Diode, zener 4.32V 1W	2		09182	1902-0797	2
VR5	Diode, zener 4.22V 400mW	1		09182	1902-3070	1

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
Z1	Dual Independent Diff. Amp	1	CA3026	02735	1820-0240	1
Z2	Resistor Network	1		09182	1810-0042	1
	A3 SLAVE BOARD - ELECTRICAL					
A3	Printed Circuit Board, Slave	1		09182	06228-60022	
C1	fxd, elect 750µF 75Vdc	1		09182	0180-1891	1
C2	fxd, elect 5µF 65Vdc	1		09182	0180-1836	1
C3	fxd, mylar .01µF 200V	1	192P10392	56289	0160-0161	1
C4	fxd, mylar .001µV 200Vdc	1	192P22292	56289	0160-0153	1
C5	fxd, mylar .1µF 200Vdc	1	192P10492	56289	0160-0168	1
C6,7	fxd, elect 1600µF 85Vdc	2		09182	0180-1986	1
C11	fxd, elect 4.7µF 35Vdc	1	150D475X9035B2	56289	0180-0100	1
C13	fxd, elect 5µF 65Vdc	1		09182	0180-1836	1
C15	fxd, mylar .47µF 25V	1	5C11B75	56289	0160-0174	1
CR1	Diode, Si. 250mW 200V	5		09182	1901-0033	5
CR2	Rect. Si. 3A 200prv	3	MR1032B	04713	1901-0416	3
CR3	Diode, Si. 250mA 75V	1		09182	1901-0050	1
CR4	Diode, Si. 400mW 15V	3		09182	1901-0461	3
CR5-7	Diode, Si. 250mW 200V			09182	1901-0033	
CR8,9	Diode, Si. 400mW 15V			09182	1901-0461	
CR10	Diode, Si. 250mW 200V			09182	1901-0033	
CR11	Diode, Si. 400mW 10V	1		09182	1901-0460	1
CR12	Rect. Si. 1A 200prv	1	1N5059	03508	1901-0327	1
CR13,14	Rect. Si. 3A 200prv		MR1032B	04713	1901-0416	
F2	Fuse Cartridge, 2A 250V Normal Blow Pigtail 3AG	1		09182	2110-0262	5
Q1,2, 7-11	NOT ASSIGNED	-	-	-	-	-
Q3	SS PNP Si.	3		09182	1853-0099	3
Q4	SS NPN Si.	5		09182	1854-0071	5
Q5	SS PNP Si.			09182	1853-0099	
Q6, 12-14	SS NPN Si.			09182	1854-0071	
Q15	SS PNP Si.			09182	1853-0099	
R1	fxd, ww 7.5KΩ ±5% 3W	1	Type 242E	56289	0811-1815	1
R2	fxd, comp (Selected) ±5% ½W	2	Type EB (obd)	01121		
R3	fxd, met. film 1KΩ ±1% 1/8W	2	Type CEA T-O	07716	0757-0280	1
R5	fxd, comp 220KΩ ±5% ½W	1	EB-2245	01121	0686-2245	1
R6	fxd, met. film 1.5KΩ ±1% 1/8W	2	Type CEA T-O	07716	0757-0427	1
R7	fxd, comp 750KΩ ±5% ½W	1	EB-7545	01121	0686-7545	1
R8	fxd, comp 75Ω ±5% ½W	1	EB-7505	01121	0686-7505	1
R9,11,14, 17,22,23, 27-29,39, 43,47,49, 53-67,78, 79,82,83	NOT ASSIGNED	-	-	-	-	-
R10	fxd, ww 1Ω ±0.5% 8W	1	Type T-7A	01686	0811-2133	1
R12	fxd, comp 3.3Ω ±5% ½W	2	EB-0335	01121	0686-0335	1
R13	fxd, met.film 200KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0472	1
R15	fxd, ww 1.3KΩ ±5% 3W	1	Type 242E	56289	0811-1803	1
R16	fxd, comp (Selected) ±5% ½W		Type EB (obd)	01121		
R18,19	fxd, comp 100Ω ±5% ½W	3	EB-1015	01121	0686-1015	1
R20	fxd, ww 1KΩ ±5% 3W	1	Type 242E	56289	0813-0001	1
R21	fxd, comp 200Ω ±5% ½W	2	EB-2015	01121	0686-2015	1
R24	var, comp 25KΩ ±30% (Zero Volt Adj.)	1		09182	2100-1534	1

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
R25	fxd, met. film 1.5KΩ ±1% 1/8W		Type CEA T-O	07716	0757-0427	
R26	fxd, met. film 249KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0270	1
R30	fxd, met. film 61.9KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0460	1
R31	fxd, met. film 2KΩ ±1% 1/8W	1	Type CEA T-O	07716	0757-0283	1
R32	fxd, met. film 3.4KΩ ±1% 1/8W	2	Type CEA T-O	07716	0698-4440	1
R33	fxd, comp 390Ω ±5% $\frac{1}{2}$ W	1	EB-3915	01121	0686-3915	1
R34	fxd, comp 10KΩ ±5% $\frac{1}{2}$ W	2	EB-1035	01121	0686-1035	1
R35	fxd, met. film 6.2KΩ ±1% 1/8W	1	Type CEA T-O	07716	0698-5087	1
R36	fxd, comp 2KΩ ±5% $\frac{1}{2}$ W	1	EB-2025	01121	0686-2025	1
R37	fxd, comp 470Ω ±5% $\frac{1}{2}$ W	2	EB-4715	01121	0686-4715	1
R38	fxd, comp 150Ω ±5% $\frac{1}{2}$ W	1	EB-1515	01121	0686-1515	1
R40	fxd, met. film 270Ω ±1% $\frac{1}{4}$W	1	Type CEB T-O	07716	0698-3506	1
R41,42	fxd, met. film 7.5KΩ ±1% 1/8W	2	Type CEA T-O	07716	0757-0440	1
R44	fxd, met. film 600Ω ±1% 1/8W	1	Type CEA T-O	07716	0757-1100	1
R45	fxd, comp 10KΩ ±5% $\frac{1}{2}$ W		EB-1035	01121	0686-1035	
R46	fxd, comp 470Ω ±5% $\frac{1}{2}$ W		EB-4715	01121	0686-4715	
R48	fxd, met. film 2KΩ ±1% $\frac{1}{4}$W	1	Type CEB T-O	07716	0757-0739	1
R50	fxd, met. film 5.49KΩ ±1% 1/8W	1	Type CEA T-O	07716	0698-3382	1
R51	fxd, comp 820Ω ±5% $\frac{1}{2}$ W	1	EB-8215	01121	0686-8215	1
R52	fxd, met. film 3.4KΩ ±1% 1/8W		Type CEA T-O	07716	0698-4440	
R68,69	fxd, ww 1Ω ±5% 3W ±20ppm	4		09182	0811-1732	1
R70	fxd, comp 3.3Ω ±5% $\frac{1}{2}$ W		EB-0335	01121	0686-0335	
R71	fxd, comp 91Ω ±5% $\frac{1}{2}$ W	1	EB-9105	01121	0686-9105	1
R72	fxd, comp 200Ω ±5% $\frac{1}{2}$ W		EB-2015	01121	0686-2015	
R73,74	fxd, ww 1Ω ±5% 3W ±20ppm			09182	0811-1732	
R77	fxd, ww 2KΩ ±5% 5W	1	Type 5XM	63743	0812-0100	1
R80	var. ww 5KΩ ±20% (Voltmeter Adj.)	1	Type 110-F4	11236	2100-1824	1
R81	fxd, met. film 57.6KΩ ±1% $\frac{1}{4}$W	1	Type CEB T-O	07716	0757-0114	1
R84	Thermistor 64Ω	1		09182	0837-0023	1
R85	fxd, met. film 42.2Ω ±1% 1/8W	1	Type CEA T-O	07716	0757-0316	1
R86	var. ww 250Ω ±20% (Ammeter Adjust)	1	Type 110-F4	11236	2100-0439	1
R87	fxd, met. film 1KΩ ±1% 1/8W		Type CEA T-O	07716	0757-0280	
R88	fxd, met. film 196Ω ±1% 1/8W	1	Type CEA T-O	07716	0698-3440	1
VR1,2	Diode, zener 6.2V 250mW	2		09182	1902-1221	2
VR3,4	Diode, zener 4.32V	2		09182	1902-0797	2
VR5	Diode, zener 4.22V 400mW	1		09182	1902-3070	1
Z1	Dual Independent Diff. Amp.	1	CA3026	02735	1820-0240	1
Z2	Resistor Network	1		09182	1810-0042	1
	A4 CROWBAR BOARD - ELECTRICAL					
A4	Printed Circuit Board, Crowbar	1		09182	06227-60023	
C1A, 1B	fxd, mylar 0.22μF 80Vdc	2	192P2249R8	56289	0160-2453	1
CR1A-3A, 1B-3B	Diode, Si. 200mA 200prv	6		09182	1901-0033	6
Q1A, 1B	SS NPN Si.	2		09182	1854-0027	2
Q2A, 2B	SS NPN Si.	2	2N3417	03508	1854-0087	2
R1A, 1B	fxd, comp 430Ω ±5% $\frac{1}{2}$W	2	EB-4315	01121	0686-4315	1
R2A, 2B	fxd, comp 200KΩ ±5% $\frac{1}{2}$W	2	EB-2045	01121	0686-2045	1
R3A, 3B	fxd, comp 10KΩ ±5% $\frac{1}{2}$W	2	EB-1035	01121	0686-1035	1
R4A, 4B	fxd, comp 3.9KΩ ±5% $\frac{1}{2}$W	2	EB-3925	01121	0686-3925	1
R5A, 5B	fxd, ww 390Ω ±5% 3W	2	Type 242E	56289	0811-1799	1
R6A, 6B	fxd, comp 4.7Ω ±5% $\frac{1}{2}$W	2	EB-47G5	01121	0698-0001	1
R7A, 7B	fxd, comp 10Ω ±5% $\frac{1}{2}$W	4	EB-1005	01121	0686-1005	1

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
R8A, 8B	fxd, met. oxide 180Ω ±5% 2W	2	Type C42S	16299	0698-3626	1
R9A, 9B	fxd, met. film 471Ω ±1% 1/8W	2	Type CEA T-0	07716	0698-5514	1
R10A, 10B	var. comp 5KΩ ±20% ½ W (Crowbar Adjust)	2		09182	2100-0011	1
R11A, 11B	fxd, comp 10Ω ±5% ½ W		EB-1005	01121	0686-1005	
T1A, 1B	Transformer, Pulse	2		09182	9100-2160	1
VR1A, 1B	Diode, zener 5.62V 400mW	2		09182	1902-3104	2
VR2A, 2B	Diode, zener 12.4V 400mW	2		09182	1902-3185	2
	FRONT PANEL - ELECTRICAL					
	Front Panel Assembly (Loaded, excluding M1)	1		09182	06228-60001	
DS1	Indicator Lamp, Neon (Line On)	1	A1C	08806	2140-0047	1
E1	5 Way Binding Post, Maroon	2	DF21MRN	58474	1510-0040	1
E2	5 Way Binding Post, Green	2	DF21GNC	58474	1510-0066	1
E3	5 Way Binding Post, Black	2	DF21BLK	58474	1510-0039	1
M1	Meter, 0-60V and 0-1.2A	2		09182	1120-1242	1
R4A, 4B	var. ww 1.1KΩ-10 Dual Concentric, (Current, Fine and Coarse)	2		09182	2100-2527	1
R27A, 27B	var. ww 10KΩ-100 Dual Concentric, (Voltage, Fine and Coarse)	2		09182	2100-2526	1
R89	fxd, comp 100Ω ±5% ½ W	1	EB-1015	01121	0686-1015	1
R90	fxd, comp 47KΩ ±5% ½ W	1	EB-4735	01121	0686-4735	1
S1	Switch, Toggle, SPST 15A (Line On)	1		09182	3101-1296	1
S2	Switch, Slide, 4PDT 3A (Mode: Tracking/Independent)	1		09182	3101-1293	1
S3A, 3B	Switch, Slide, 3PDT 3A (Meter: Volts/Amperes)	2		09182	3101-1288	1
	REAR PANEL - ELECTRICAL					
E4	5 Way Binding Post (GND)	1		09182	1510-0044	1
F1 (115V)	Fuse Cartridge, 4A 250V 3AG	1	312.004	75915	2110-0055	5
F2 (230V)	Fuse Cartridge, 2A 250V 3AG	1	312.002	75915	2110-0002	5
P1	Power Cord, AC Line	1	KH-4096	70903	8120-0050	1
Q8A-9A, 8B-9B	Power NPN Si.	4		09182	1854-0225	4
Q10A-11A Q10B-11B	Power NPN Si.	4		09182	1854-0239	4
S5	Switch, Slide, DPDT (115/230V Line Selector)	1		09182	3101-1234	1
	CHASSIS - ELECTRICAL					
CR4A, 4B	SCR, 12.5A 600prv	2	2N3669	02735	1884-0019	2
Q7A, 7B	Power PNP Si.	2		09182	1853-0052	2
	P. C. BOARDS - MECHANICAL					
	Hex Nut Bushing	2		09182	2950-0334	
	Bushing	2		09182	1410-0052	
	Barrier Block	2		09182	0360-1573	
	Jumper	14		09182	0360-1143	

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
	FRONT PANEL - MECHANICAL					
	Meter Trim, Top	1		09182	5020-5770	
	Bezel, Meter, 3½"	2		09182	4040-0483	1
	Meter Combining Pin	1		09182	1480-0181	1
	Front Panel, Basic	1		09182	5020-5773	
	Front Panel, Control Section Insert	1		09182	5000-6265	
	Front Panel, Output Section Insert	1		09182	5000-6266	
	Corporate Logo	1		09182	7120-1254	
	Knob	4		09182	0370-0179	1
	Knob	4		09182	0370-0101	1
	Knurled Nut (R4A, R4B, R27A, R27B)	4	76320NP	73734	0590-0856	1
	Lampholder, Clear, DS1	1		09182	5040-0234	1
	Lampholder, Base, DS1	1		09182	5040-0235	1
	Stand, Tilt, Foot Assembly	1		09182	1490-0032	
	Hinge, Foot Assembly	2		09182	5040-0700	
	Foot Assembly	1		09182	5060-0728	
	REAR PANEL - MECHANICAL					
	Heat Sink, Rear Panel, Q8-11 (A & B)	1		09182	5020-5774	
	Rear Panel - Lower	1		09182	5000-6264	
	Rear Panel - Upper	1		09182	5000-6263	
	Cover, Rear Barrier Strips	2		09182	5000-6275	
	Shoulder Washer (CR4A, 4B Q7A, 7B)	8		09182	2190-0491	6
	Bushing, Insulator (Q7A, 7B)	2		09182	0340-0171	2
	Insulator, Mica (Q7A, 7B)	2		09182	0340-0180	2
	Insulator, Mica (CR4A, 4B Q8-11A, Q8-11B)	10		09182	0340-0174	6
	Serial Plate	1		09182	7120-1111	
	Bushing, Insulator, Emitter-Base, Q8-11 (A & B), CR4A, CR4B	20		09182	0340-0166	8
	Bushing, Insulator, Collector Screws, Q8-11 (A & B)	16		09182	0340-0168	8
	Fuseholder, F1	1	342014	75915	1400-0084	1
	Hex Nut, Fuseholder	1		09182	2950-0038	1
	Lockwasher, Fuseholder	1		09182	2190-0037	1
	Flat Neoprene Washer, Fuseholder	1		09182	1400-0090	1
	Spacer	4		09182	0380-0912	1
	Solder Lug, 6-32, Q7A, Q7B	2	(obd)	09182	-	
	Strain Relief Bushing	1		09182	0400-0013	
	CHASSIS ASSEMBLY - MECHANICAL					
	Chassis, Center	1		09182	5000-6262	
	Cover, Side	2		09182	5000-6145	
	Cover, Top	1		09182	5060-0724	
	Cover, Bottom	1		09182	5000-6261	
	Fastener, Top and Bottom Covers	4		09182	0590-0052	
	Side Frame Assembly	2		09182	5060-0703	
	Cable Clamp	2		09182	1400-0718	1
	Guide, Printed Circuit Boards	4		09182	0403-0150	
	MISCELLANEOUS					
	Manual	1		09182	06227-90001	
	Carton, Packing	1		09182	9211-1183	
	Floater Pad, Packing	2		09182	9220-1404	
	Fuse Envelope, F1 (230V)	1		09182	9320-0234	

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
	OPTION 007: 10-Turn Voltage Control					
R4A,4B	var. ww 1KΩ ±5% 2W, 10-Turn	2		09182	2100-1864	1
	Knob, Black (R4A,R4B)	2		09182	0370-0846	1
	OPTION 008: 10-Turn Current Control					
R27A,27B	var. ww 10KΩ ±5% 2W, 10-Turn	2		09182	2100-1866	1
	Knob, Black (R27A,R27B)	2		09182	0370-0846	1
	OPTION 009: 10-Turn Voltage & Current Controls					
R4A,4B	var. ww 1KΩ ±5% 2W, 10-Turn	2		09182	2100-1864	1
R27A,27B	var. ww 10KΩ ±5% 2W, 10-Turn	2		09182	2100-1866	1
	Knob, Black (R4A,R4B,R27A,R27B)	4		09182	0370-0846	1
	OPTION 013: 3 Digit Decadial Voltage Control					
R4A,4B	var. ww 1KΩ ±5% 2W, 10-Turn	2		09182	2100-1864	1
	Knob, Black (R4A,R4B)	2		09182	0370-0846	1
	3-Digit Decadial	1	RD-411	07716	1140-0020	1
	OPTION 014: 3 Digit Decadial Current Control					
R27A,27B	var. ww 10KΩ ±5% 2W, 10-Turn	2		09182	2100-1866	1
	Knob, Black (R27A,R27B)	2		09182	0370-0846	1
	3-Digit Decadial	1	RD-411	07716	1140-0020	1
	OPTION 015: 3 Digit Decadial Voltage and Current Controls					
R4A,4B	var. ww 1KΩ ±5% 2W, 10-Turn	2		09182	2100-1864	1
R27A,27B	var. ww 10KΩ ±5% 2W, 10-Turn	2		09182	2100-1866	1
	Knob, Black (R4A,R4B,R27A,R27B)	4		09182	0370-0846	1
	3-Digit Decadial	2	RD-411	07716	1140-0020	1

SECTION VII
SCHEMATIC DIAGRAM AND COMPONENT LOCATION DIAGRAMS

This section contains the diagrams necessary for the operation and maintenance of this power supply. Included are:

a. Component location diagrams (Figures 7-1 through 7-6), showing the physical location and reference designators of parts mounted on the printed circuit boards and chassis.

b. The schematic diagram (Figure 7-7), illustrating the circuitry for the entire power supply. Test points (encircled numbers) are given on the schematic. These points coincide with the test points on the component location diagrams and are referred to throughout the text. Voltages are given in italics adjacent to the test points.

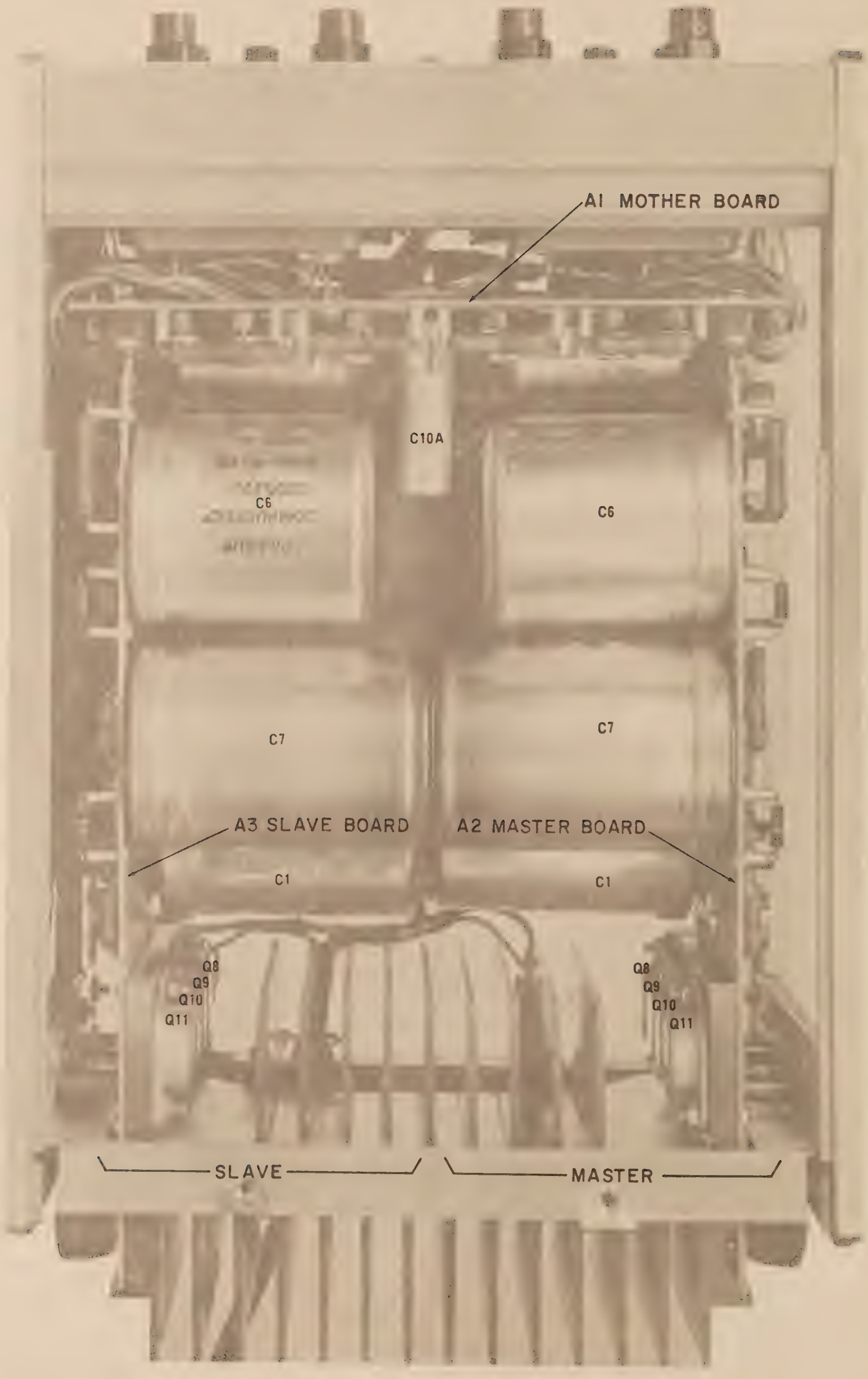


Figure 7-1. Main Chassis Component Location Diagram, Top View

Figure 7-2. Main Chassis Component Location Diagram, Bottom View

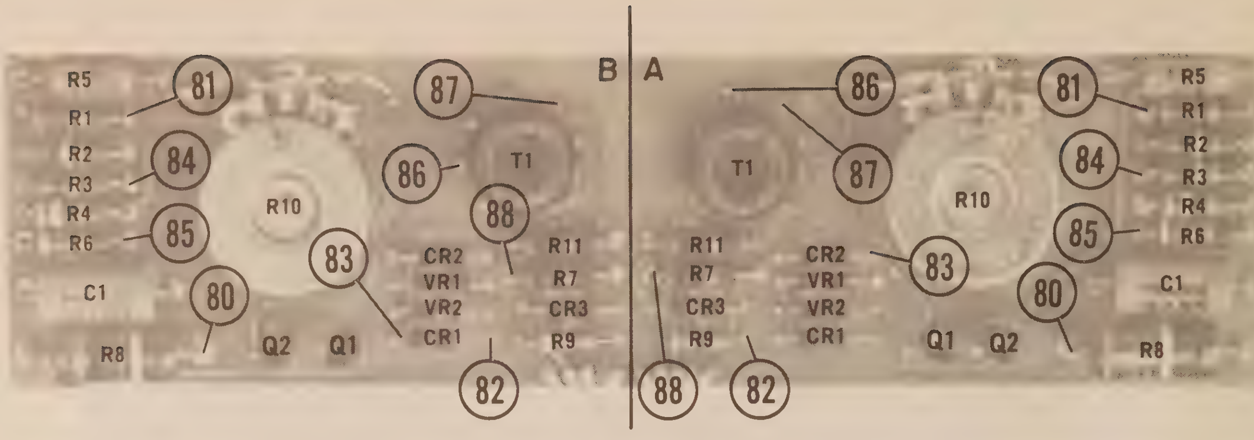
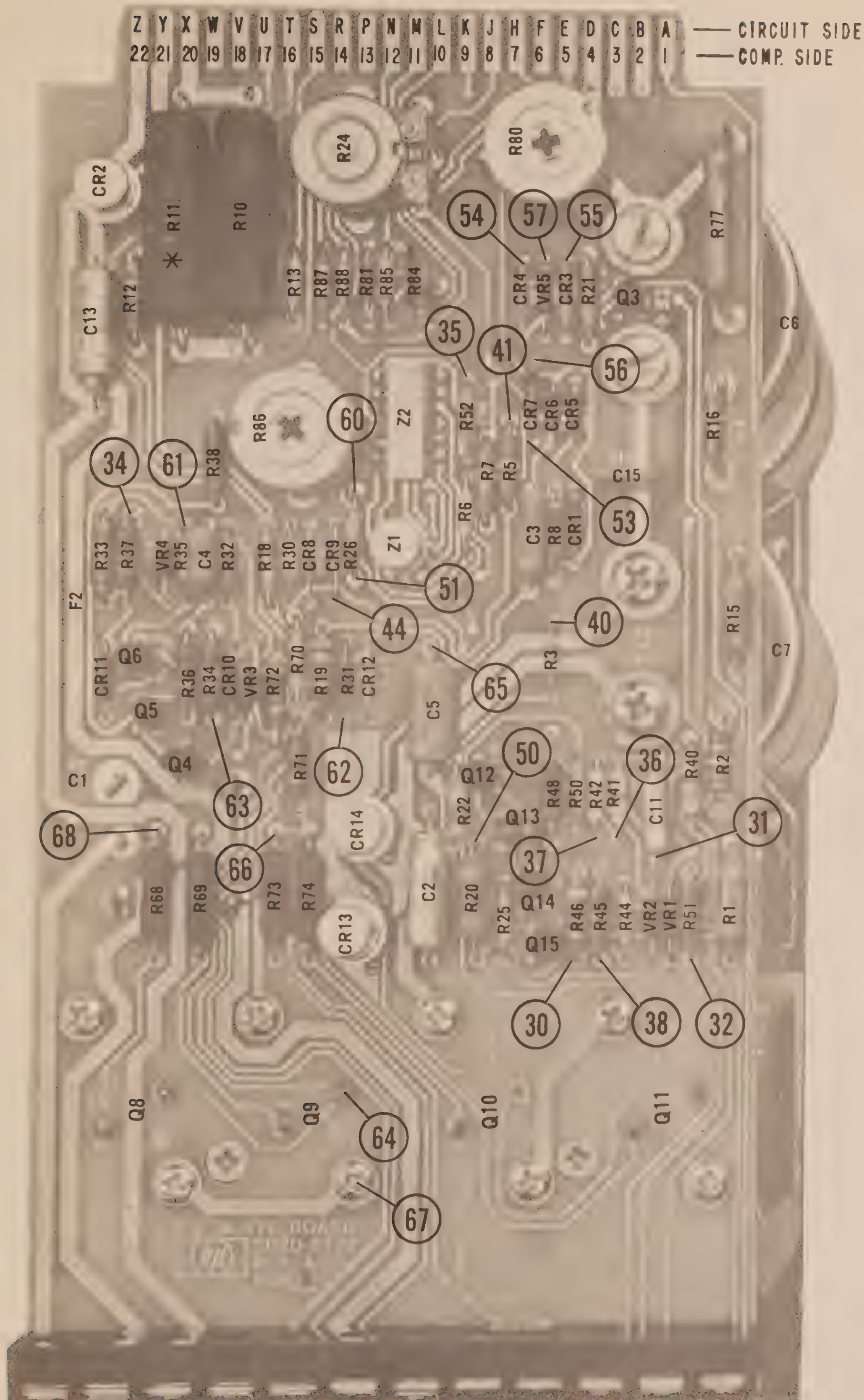


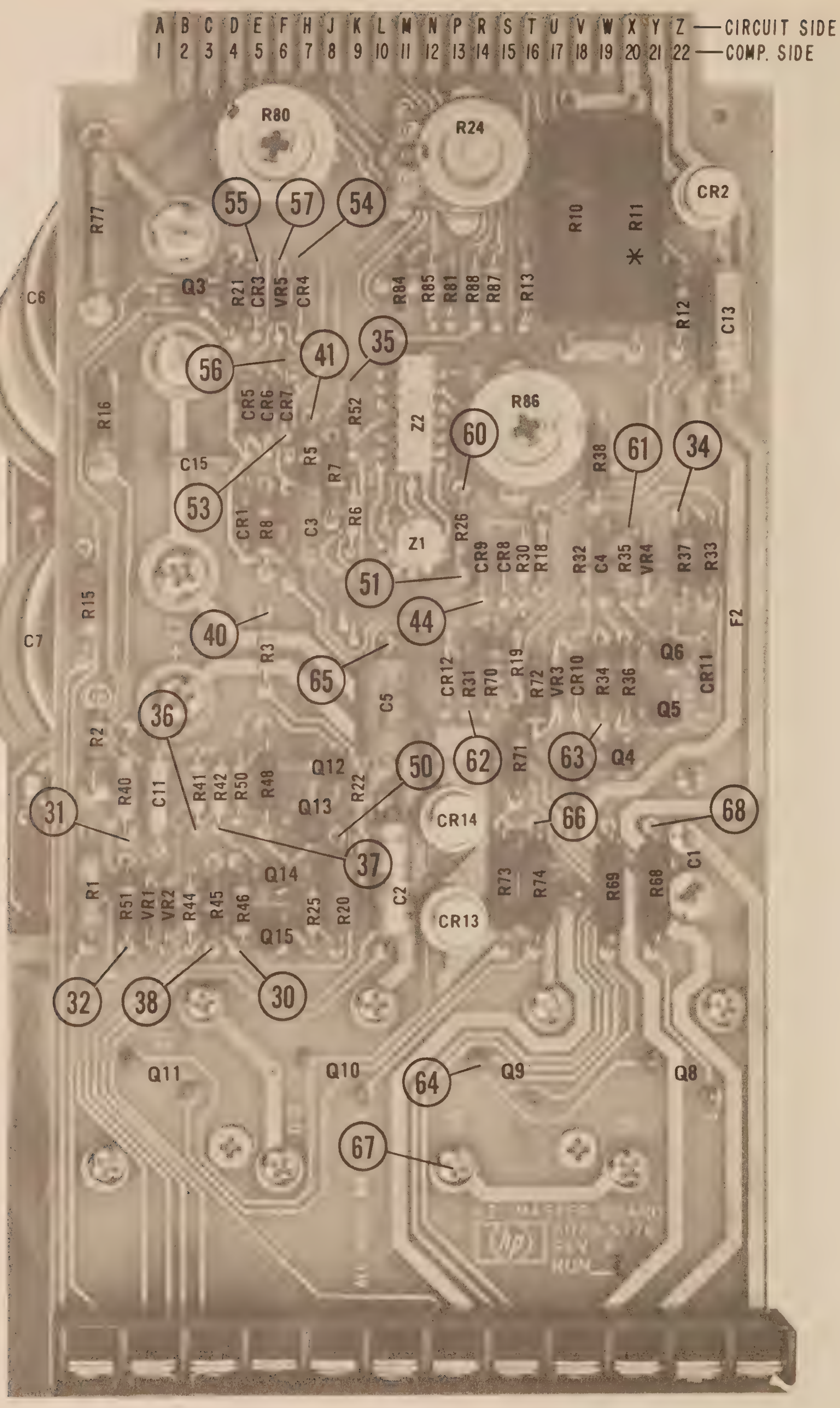
Figure 7-3. A4 Crowbar Printed Circuit Board
Component Location Diagram

Figure 7-4. A1 Mother Printed Circuit Board
Component Location Diagram



✱-NOT USED ON 6228B

Figure 7-5. A3 Slave Printed Circuit Board Component Location Diagram



* – NOT USED ON 6228B

Figure 7-6. A2 Master Printed Circuit Board Component Location Diagram

1. ALL RESISTORS ARE I
2. ALL 1/4W AND 1/8W R
3. ALL CAPACITORS ARE IN
4. REAR TERMINALS ARE
5. MODE SWITCH SHOWN
6. DC VOLTAGES WERE ME
   A. HEWLETT-PACKAR
   B. 115VAC INPUT.
   C. SUPPLY IN CONST
   D. CURRENT CONTRO
   E. VOLTAGES REFER
   F. VOLTAGES ARE T
7. † DENOTES NOMINAL V
8. ‡ DENOTES CHASSIS MO
9. ✱ DENOTES ±20PPM W
10. ENCLOSES
11. ENCLOSES
12. DENOTES FO
13. DENOTES F
14. —<7<— NUMBER OR DESIGNATES
15. LETTERS (A) AND (B) SUPPLIES, RESPECTIV
16. PIN LOCATION DIAGRA

17. SCHEMATIC DIAGRAM F

18. SCHEMATIC DIAGRAM

19. MODE SWITCH S2 AND

SWINGER

S

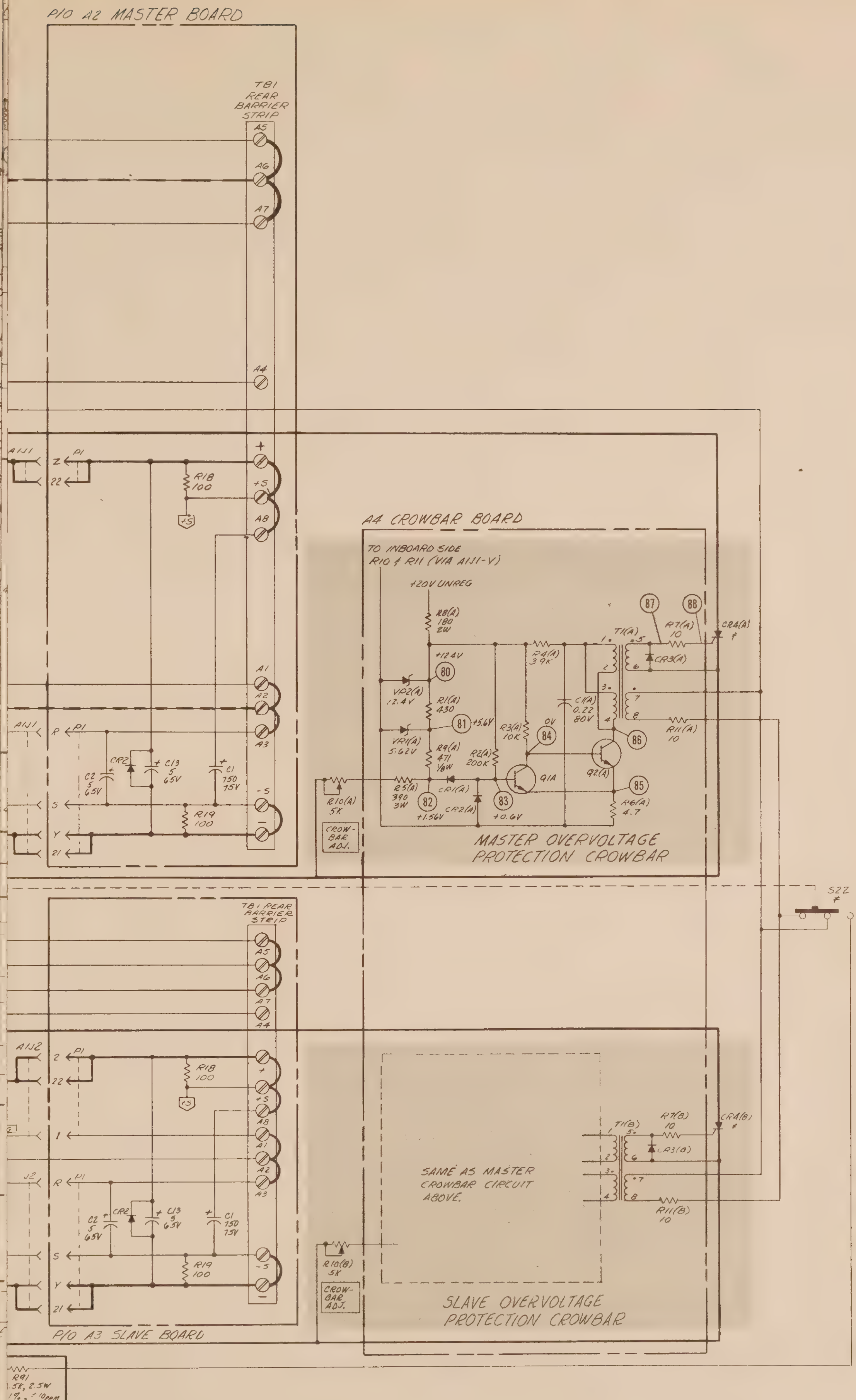
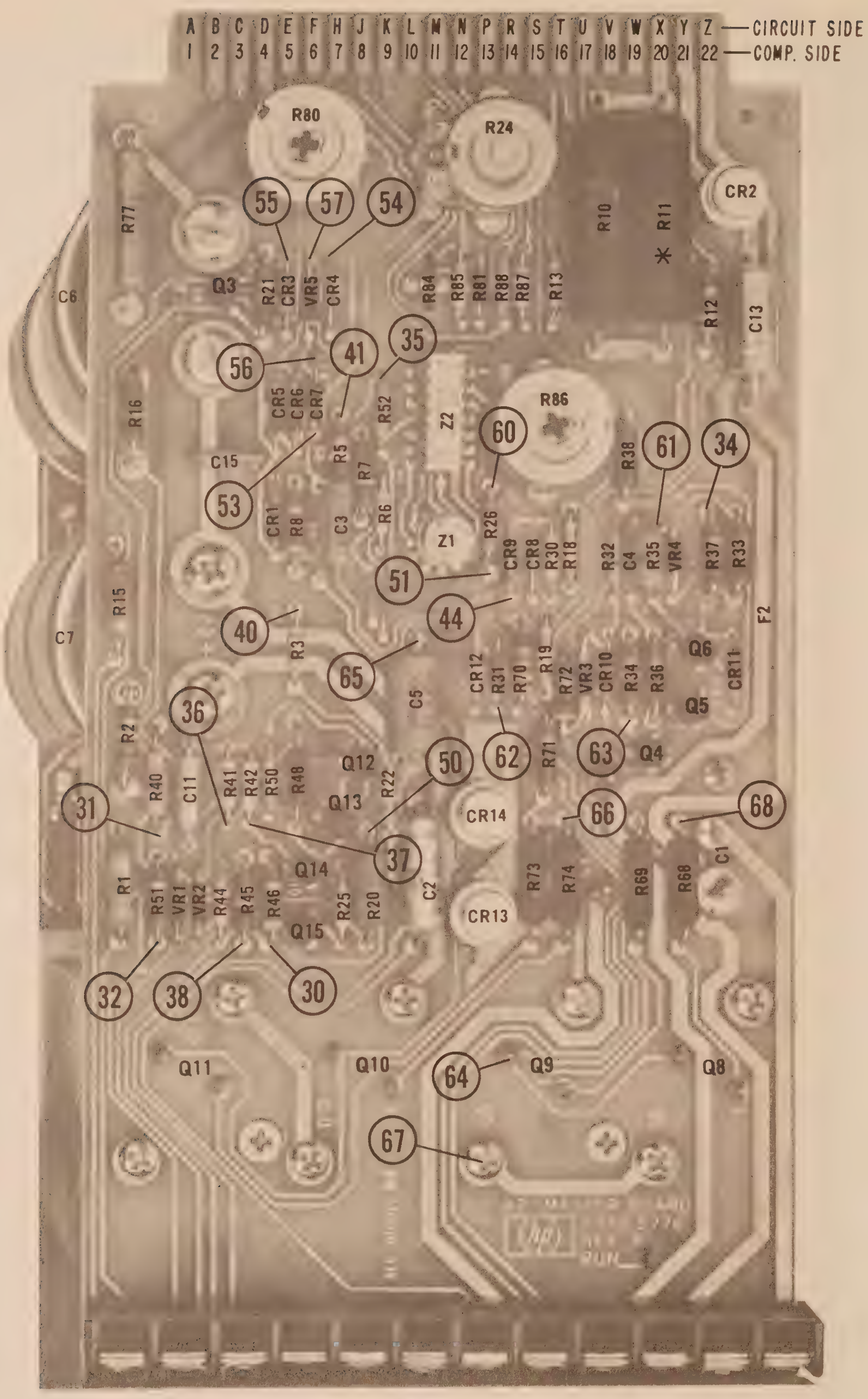


Figure 7-7. Model 6228B, Schematic Diagram

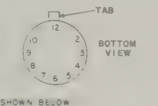


∗ - NOT USED ON 6228B

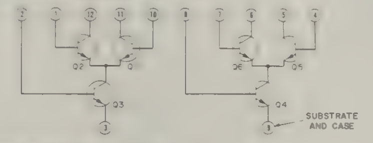
Figure 7-6. A2 Master Printed Circuit Board
Component Location Diagram

SCHEMATIC NOTES

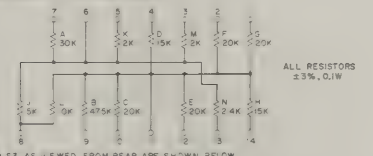
1. ALL RESISTORS ARE IN OHMS, 1/2W, ±5% UNLESS OTHERWISE NOTED.
2. ALL 1/4W AND 1/8W RESISTORS ARE ±1% UNLESS OTHERWISE NOTED.
3. ALL CAPACITORS ARE IN MICROFARADS UNLESS OTHERWISE NOTED
4. REAR TERMINALS ARE SHOWN IN NORMAL STRAPPING FOR USE OF FRONT PANEL CONTROLS
5. MODE SWITCH SHOWN IN INDEPENDENT POSITION, METER SWITCH SHOWN IN AMPS POSITION.
6. DC VOLTAGES WERE MEASURED UNDER THE FOLLOWING CONDITIONS:
   A. HEWLETT PACKARD 427A OR EQUIVILENT
   B. 115VAC INPUT
   C. SUPPLY IN CONSTANT VOLTAGE OPERATION AT MAXIMUM RATED OUTPUT VOLTAGE WITH NO LOAD CONNECTED.
   D. CURRENT CONTROLS AND CROWBAR ADJUST CONTROLS TURNED FULLY CLOCKWISE; MODE SWITCH IN INDEPENDENT POSITION.
   E. VOLTAGES REFERENCED TO +S UNLESS OTHERWISE NOTED
   F. VOLTAGES ARE TYPICAL ±10% UNLESS OTHERWISE NOTED.
7. † DENOTES NOMINAL VALUE COMPONENT SELECTED FOR OPTIMUM PERFORMANCE.
8. ♦ DENOTES CHASSIS MOUNTED COMPONENTS
9. ✱ DENOTES ±20PPM WIRE TEMPERATURE COEFFICIENT.
10. ENCLOSES FRONT PANEL MARKING.
11. ENCLOSES REAR PANEL MARKING.
12. DENOTES FORWARD SIGNAL PATH OF THE VOLTAGE FEEDBACK LOOP.
13. DENOTES FORWARD SIGNAL PATH OF THE CURRENT FEEDBACK LOOP
14. —<7←— NUMBER OR LETTER REFERS TO PIN OF A1J1: NUMBER DESIGNATES CONTACT ON COMPONENT SIDE OF PLUG-IN BOARD; LETTER DESIGNATES CONTACT ON CIRCUIT SIDE OF PLUG-IN BOARD (SEE FIGURES 7-5 AND 7-6).
15. LETTERS (A) AND (B) ON A1 MOTHER BOARD AND A4 CROWBAR BOARD DESIGNATE COMPONENTS ASSOCIATED WITH MASTER AND SLAVE SUPPLIES, RESPECTIVELY
16. PIN LOCATION DIAGRAM FOR INTEGRATED CIRCUIT Z1 IS SHOWN BELOW:



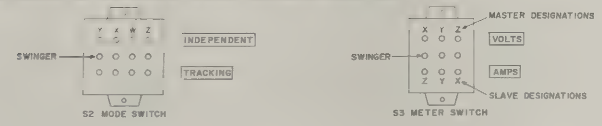
7 SCHEMATIC DIAGRAM FOR INTEGRATED CIRCUIT Z IS SHOWN BELOW



8 SCHEMATIC DIAGRAM FOR INTEGRATED CIRCUIT Z2 IS SHOWN BELOW



9 MODE SWITCH S2 AND METER SWITCH S3 AS VIEWED FROM REAR ARE SHOWN BELOW



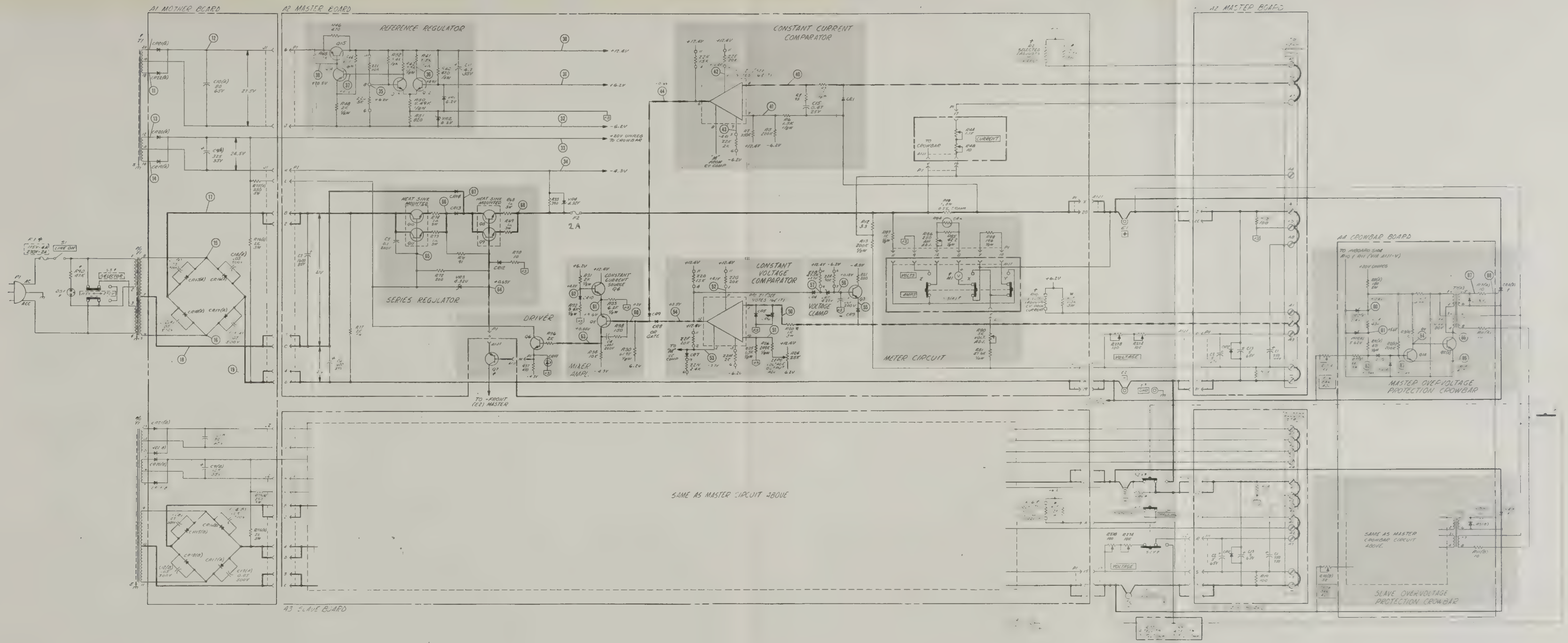


Figure 7-7. Model 6228B, Schematic Diagram

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MANUAL CHANGES

Model 6228B DC Power Supply
Manual HP Part No. 06516-90001

Make all corrections in the manual according to errata below, then check the following table for your power supply serial number and enter any listed change(s) in the manual.

SERIAL		MAKE CHANGES
Prefix	Number	
1020A	00121 - up	1
ALL	-	Errata

▶ CHANGE 1:

The serial number prefix of the instrument has been changed from 0E to 1020A.

In the replaceable parts list and on the schematic diagram, make the following changes:

CR6: Disconnect anode from junction of CR5 and R20 and connect instead to junction of CR3 and R20, on A2 and A3 boards.

R22: Add, 24Ω, $\frac{1}{2}$W, ±5%, HP Part No. 0686-2405, connected in series with positive side of C2 on A2 and A3 boards.

R70: Change to 10Ω, $\frac{1}{2}$W, ±5%, HP Part No. 0686-1005, on A2 and A3 boards.

R84: Delete from A2 and A3 boards.

▶ ERRATA:

In the replaceable parts list, make the following changes:

A4 (Crowbar Printed Circuit Board): Change the HP Part No. to 06228-60023.

Q7A, 7B: Change to 2N5954, HP Part No. 1850-0277.

In the replaceable parts list and on the schematic diagram, make the following change:

VR1 (A), VR1 (B): Change to diode, zener, 6.19V, 400mW, HP Part No. 1902-0049.

OPTION 007 and 008: Interchange the parts listed under these two options (R4A and B belong with Option 008, and R27A and B belong with Option 007).

OPTION 013, 014, and 015: Delete Knobs.

6-22-70

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MANUAL CHANGES

Model 6228B DC Power Supply
Manual HP Part No. 06516-90001

Make all corrections in the manual according to errata below, then check the following table for your power supply serial number and enter any listed change(s) in the manual.

SERIAL		MAKE CHANGES
Prefix	Number	
1020A	00121 - up	1
ALL	-	Errata

▶ CHANGE 1:

The serial number prefix of the instrument has been changed from 0E to 1020A.

In the replaceable parts list and on the schematic diagram, make the following changes:

CR6: Disconnect anode from junction of CR5 and R20 and connect instead to junction of CR3 and R20, on A2 and A3 boards.
R22: Add, 24Ω, $\frac{1}{2}$W, ±5%, HP Part No. 0686-2405, connected in series with positive side of C2 on A2 and A3 boards.
R70: Change to 10Ω, $\frac{1}{2}$W, ±5%, HP Part No. 0686-1005, on A2 and A3 boards.
R84: Delete from A2 and A3 boards.

▶ ERRATA:

In the replaceable parts list, make the following changes:

A4 (Crowbar Printed Circuit Board): Change the HP Part No. to 06228-60023.
Q7A, 7B: Change to 2N5954, HP Part No. 1850-0277.

In the replaceable parts list and on the schematic diagram, make the following change:

VR1 (A), VR1 (B): Change to diode, zener, 6.19V, 400mW, HP Part No. 1902-0049.

OPTION 007 and 008: Interchange the parts listed under these two options (R4A and B belong with Option 008, and R27A and B belong with Option 007).
OPTION 013, 014, and 015: Delete Knobs.

6-22-70

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MANUAL CHANGES

Model 6228B DC Power Supply
Manual HP Part No. 06516-90001

Make all corrections in the manual according to errata below, then check the following table for your power supply serial number and enter any listed change(s) in the manual.

SERIAL		MAKE CHANGES
Prefix	Number	
1020A	00121 - up	1
ALL	-	Errata

▶ CHANGE 1:

The serial number prefix of the instrument has been changed from 0E to 1020A.

In the replaceable parts list and on the schematic diagram, make the following changes:

CR6: Disconnect anode from junction of CR5 and R20 and connect instead to junction of CR3 and R20, on A2 and A3 boards.
R22: Add, 24Ω, $\frac{1}{2}$W, ±5%, HP Part No. 0686-2405, connected in series with positive side of C2 on A2 and A3 boards.
R70: Change to 10Ω, $\frac{1}{2}$W, ±5%, HP Part No. 0686-1005, on A2 and A3 boards.
R84: Delete from A2 and A3 boards.

▶ ERRATA:

In the replaceable parts list, make the following changes:

A4 (Crowbar Printed Circuit Board): Change the HP Part No. to 06228-60023.
Q7A, 7B: Change to 2N5954, HP Part No. 1850-0277.

In the replaceable parts list and on the schematic diagram, make the following change:

VR1 (A), VR1 (B): Change to diode, zener, 6.19V, 400mW, HP Part No. 1902-0049.

OPTION 007 and 008: Interchange the parts listed under these two options (R4A and B belong with Option 008, and R27A and B belong with Option 007).
OPTION 013, 014, and 015: Delete Knobs.

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